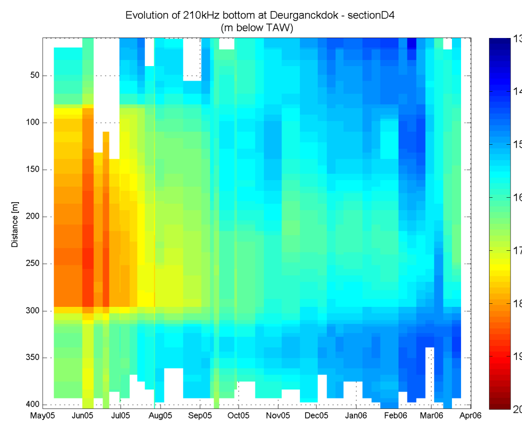
VLAAMSE OVERHEID

DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN
WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing

Bestek 16EB/05/04

Deurganckdok– Evolution of water-bed interface in a cross-section of Deurganckdok



Deelrapport 1.5: Sediment jaarbalans 01/04/2006 – 31/03/2007

Report 1.5: Annual sediment balance 01/04/2006 – 31/03/2007

17 April 2008

I/RA/11283/06.117/MSA

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en

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Document Control Sheet

Document Identification

Title:	Deelrapport 1.5: Sediment jaarbalans 01/04/2006 – 31/03/2007
Project:	Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing
Client	Waterbouwkundig Laboratorium
File reference:	I/RA/11283/06.117/MSA
File name	K:\PROJECTS\11\11283 - Opvolging aanslibbing dgd\10-Rap\DGD1\DeelOpdracht1_Slibbalans\1_05_RA06117_AnnualSedBalance2006-2007\RA06117_SedBalance_2006-2007_v30_MSA.doc

Revisions

Version	Date	Author	Description
3.0	17/04/2008	BOB/MBO	Final report
2.0	18/10/2007	BOB/MBO	Final report
1.0	21/09/2007	BOB/MBO	Concept

Distribution List

Name	# ex.	Company/authorities	Position in reference to the project
Yves Plancke	7	Waterbouwkundig Laboratorium	Client
Frederik Roose	3	Afdeling Maritieme Toegang	Client

Approval

Version	Date	Author	Project manager	Commissioner
3.0	17/04/2008	BOB/MBO	MSA	MSA
2.0	18/10/2007	BOB/MBO	MSA	MSA
1.0	21/09/2007	BOB/MBO	MSA	MSA

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GLOSSARY

BIS	Dredging Information System used in the Lower Sea Scheldt
d	Density of dredged sediment [kg/dm³]
DGD	Deurganckdok
HCBS	High Concentration Benthic Suspensions
M	mass of dry solids [ton]
ρ_s	density of the solid minerals [kg/dm³]
ρ_w	density of clear water [kg/dm³]
t_{0d}	Reference situation for densimetric analysis (empty dock)
t_{0e}	Reference situation for volumetric analysis (24 March 2006)
TDS	Ton of dry solids [ton]
V	volume of dredged sediment [m³]

1. INTRODUCTION

1.1. The assignment

This report is part of the set of reports describing the results of the long-term measurements conducted in Deurganckdok aiming at the monitoring and analysis of silt accretion. This measurement campaign is an extension of the study “Extension of the study about density currents in the Beneden Zeeschelde” as part of the Long Term Vision for the Scheldt estuary. It is complementary to the study ‘Field measurements high-concentration benthic suspensions (HCBS 2)’.

The terms of reference for this study were prepared by the ‘Departement Mobiliteit en Openbare Werken van de Vlaamse Overheid, Afdeling Waterbouwkundig Laboratorium’ (16EB/05/04). The repetition of this study was awarded to International Marine and Dredging Consultants NV in association with WL|Delft Hydraulics and Gems International on 10/01/2006.

Waterbouwkundig Laboratorium – Cel Hydrometrie Schelde provided data on discharge, tide, salinity and turbidity along the river Scheldt and provided survey vessels for the long term and through tide measurements. Afdeling Maritieme Toegang provided maintenance dredging data. Agentschap voor Maritieme Dienstverlening en Kust – Afdeling Kust and Port of Antwerp provided depth sounding measurements.

The execution of the study involves a twofold assignment:

- Part 1: Setting up a sediment balance of Deurganckdok covering a period of one year
- Part 2: An analysis of the parameters contributing to siltation in Deurganckdok

1.2. Purpose of the study

The Lower Sea Scheldt (Beneden Zeeschelde) is the stretch of the Scheldt estuary between the Belgium-Dutch border and Rupelmonde, where the entrance channels to the Antwerp sea locks are located. The navigation channel has a sandy bed, whereas the shallower areas (intertidal areas, mud flats, salt marshes) consist of sandy clay or even pure mud sometimes. This part of the Scheldt is characterised by large horizontal salinity gradients and the presence of a turbidity maximum with depth-averaged concentrations ranging from 50 to 500 mg/l at grain sizes of 60 - 100 µm. The salinity gradients generate significant density currents between the river and the entrance channels to the locks, causing large siltation rates. It is to be expected that in the near future also the Deurganckdok will suffer from such large siltation rates, which may double the amount of dredging material to be dumped in the Lower Sea Scheldt.

Results from the study may be interpreted by comparison with results from the HCBS and HCBS2 studies covering the whole Lower Sea Scheldt. These studies included through-tide measurement campaigns in the vicinity of Deurganckdok and long term measurements of turbidity and salinity in and near Deurganckdok.

The first part of the study focuses on obtaining a sediment balance of Deurganckdok. Aside from natural sedimentation, the sediment balance is influenced by the maintenance and capital dredging works. This involves sediment influx from capital dredging works in the Deurganckdok, and internal relocation and removal of sediment by maintenance dredging works. To compute a sediment balance an inventory of bathymetric data (depth soundings), density measurements of the deposited material and detailed information of capital and maintenance dredging works will be made up.

The second part of the study is to gain insight in the mechanisms causing siltation in Deurganckdok, it is important to follow the evolution of the parameters involved, and this on a long and short term basis (long term & through-tide measurements). Previous research has shown the importance of water exchange at the entrance of Deurganckdok is essential for understanding sediment transport between the dock and the Scheldt river.

1.3. Overview of the reports

1.3.1. Reports

Reports of the project 'Opvolging aanslibbing Deurganckdok' are summarized in Table 1-1.

Reports of the measurement campaign HCBS2 for which the winter campaign has been carried out simultaneously with the trough tide measurements in this project are listed in APPENDIX F.

Table 1-1: Overview of Deurganckdok Reports

Report	Description
Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.1	Sediment Balance: Three monthly report 1/4/2006 – 30/06/2006 (I/RA/11283/06.113/MSA)
1.2	Sediment Balance: Three monthly report 1/7/2006 – 30/09/2006 (I/RA/11283/06.114/MSA)
1.3	Sediment Balance: Three monthly report 1/10/2006 – 31/12/2006 (I/RA/11283/06.115/MSA)
1.4	Sediment Balance: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.116/MSA)
1.5	Annual Sediment Balance (I/RA/11283/06.117/MSA)
1.6	Sediment balance Bathymetry: 2005 – 3/2006 (I/RA/11283/06.118/MSA)
Factors contributing to salinity and sediment distribution in Deurganckdok: Salinity-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP)	
2.1	Through tide measurement Siltprofiler 21/03/2006 Laure Marie (I/RA/11283/06.087/WGO)
2.2	Through tide measurement Siltprofiler 26/09/2006 Stream (I/RA/11283/06.068/MSA)
2.3	Through tide measurement Sediview spring tide 22/03/2006 Veremans (I/RA/11283/06.110/BDC)
2.4	Through tide measurement Sediview spring tide 27/09/2006 Parel 2 (I/RA/11283/06.119/MSA)
2.5	Through tide measurement Sediview neap tide (to be scheduled) (I/RA/11283/06.120/MSA)
2.6	Salinity-Silt distribution & Frame Measurements Deurganckdok 13/3/2006 – 31/05/2006 (I/RA/11283/06.121/MSA)
2.7	Salinity-Silt distribution & Frame Measurements Deurganckdok 15/07/2006 – 31/10/2006 (I/RA/11283/06.122/MSA)

Report	Description
2.8	Salinity-Silt distribution & Frame Measurements Deurganckdok 15/01/2007 – 15/03/2007 (I/RA/11283/06.123/MSA)
Boundary Conditions: Upriver Discharge, Salinity Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels	
3.1	Boundary conditions: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.127/MSA)
Analysis	
4.1	Analysis of Siltation Processes and Factors (I/RA/11283/06.129/MSA)

1.3.2. Measurement actions

Following measurements have been carried out during the course of this project:

1. Monitoring upstream discharge in the Scheldt river
2. Monitoring Salinity and sediment concentration in the Lower Sea Scheldt taken from permanent data acquisition sites at Lillo, Oosterweel and up- and downstream of the Deurganckdok.
3. Long term measurement of salinity distribution in Deurganckdok.
4. Long term measurement of sediment concentration in Deurganckdok
5. Monitoring near-bed processes in the central trench in the dock, near the entrance as well as near the landward end: near-bed turbidity, near-bed current velocity and bed elevation variations are measured from a fixed frame placed on the dock's bed.
6. Measurement of current, salinity and sediment transport at the entrance of Deurganckdok for which ADCP backscatter intensity over a full cross section are calibrated with the Sediview procedure and vertical sediment and salinity profiles are recorded with the SiltProfiler equipment
7. Through tide measurements of vertical sediment concentration profiles -including near bed highly concentrated suspensions- with the SiltProfiler equipment. Executed over a grid of points near the entrance of Deurganckdok.
8. Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks
9. Monitoring dredging and dumping activities in the Lower Sea Scheldt

In situ calibrations were conducted on 15 March 2006, 14 April 2006, 23 June 2006 and 18 September 2006 to calibrate all turbidity and conductivity sensors (IMDC, 2006f & IMDC, 2007l).

1.4. Structure of the report

This report presents the annual sediment balance of the Deurganckdok for the period of 01/04/2006 to 31/03/2007. The first chapter comprises an introduction. The second chapter describes the project. Chapter 3 deals with the collected data over the one-year measurement period, whereas the method of data processing is presented in Chapter 4. Chapter 5 gives an analysis of the one-year dataset. Finally, Chapter 6 will discuss some limitations of the actual data set and recommendations to make a sediment mass balance of the dock possible.

2. SEDIMENTATION IN DEURGANCKDOK

2.1. Project Area: Deurganckdok

Deurganckdok is a tidal dock situated at the left bank in the Lower Sea Scheldt, between Liefkenshoek and Doel. Deurganckdok has the following characteristics:

1. The dock has a total length of 2750 m and is 450 m wide at the Scheldt end and 400 m wide at the inward end of the dock
2. The bottom of Deurganckdok is provided at a depth of –17m TAW in the transition zones between the quay walls and the central trench. The bottom in the central trench is designed at –19 m TAW.
3. The quay walls reach up to +9m TAW

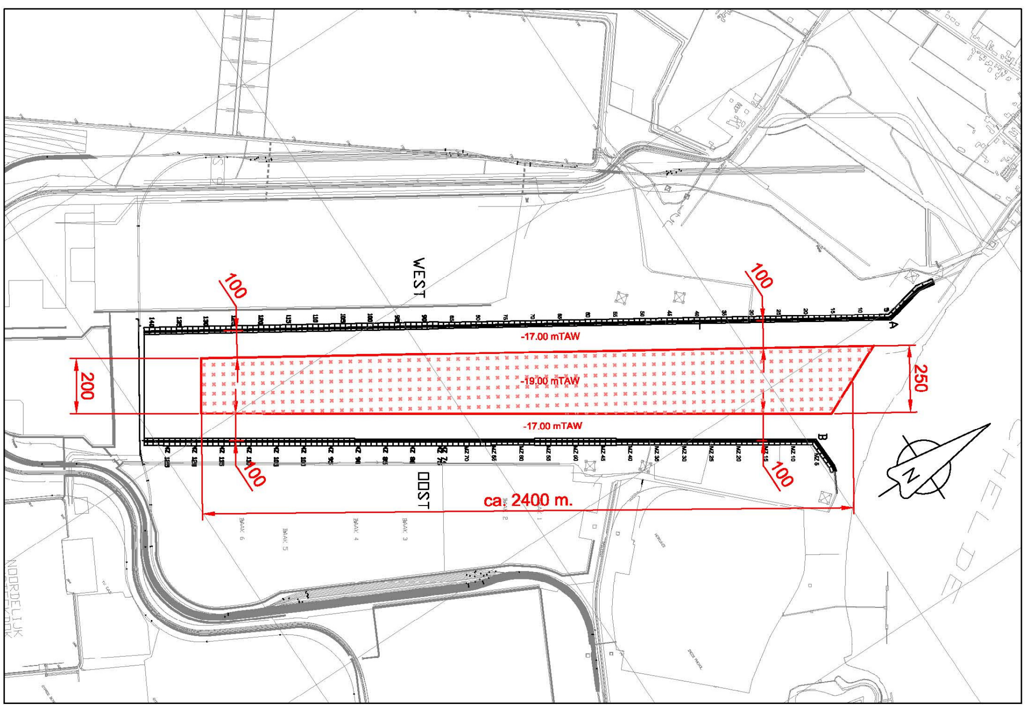

Figure 2-1: Overview of Deurganckdok

The dredging of the dock is performed in 3 phases. On 18 February 2005 the dike between the Scheldt and the Deurganckdok was breached. On 6 July 2005 Deurganckdok was officially opened. The second dredging phase was finalized a few weeks later. The first terminal operations have started since. In February 2007, the third dredging phase started and is planned to be finalised in 12 months time (by February 2008).

2.2. Overview of the studied parameters

The first part of the study aims at determining a sediment balance of Deurganckdok and the net influx of sediment. The sediment balance comprises a number of sediment transport modes: deposition, influx from capital dredging works, internal replacement and removal of sediments due to maintenance dredging (Figure 2-2).

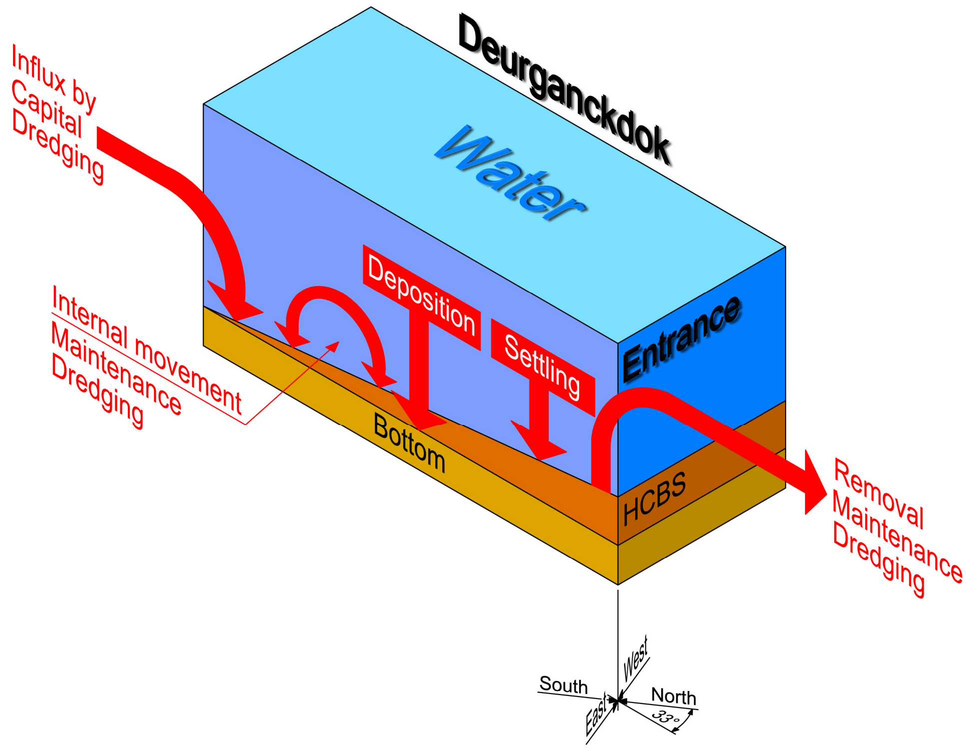

Figure 2-2: Elements of the sediment balance

A net deposition can be calculated from a comparison with a chosen initial condition t_0 (Figure 2-3). The mass of deposited sediment is determined from the integration of bed density profiles recorded at grid points covering the dock. Subtracting bed sediment mass at t_0 leads to the change in mass of sediments present in the dock (mass growth). Adding cumulated dry matter mass of dredged material removed since t_0 and subtracting any sediment influx due to capital dredging works leads to the total cumulated mass entered from the Scheldt river since t_0.

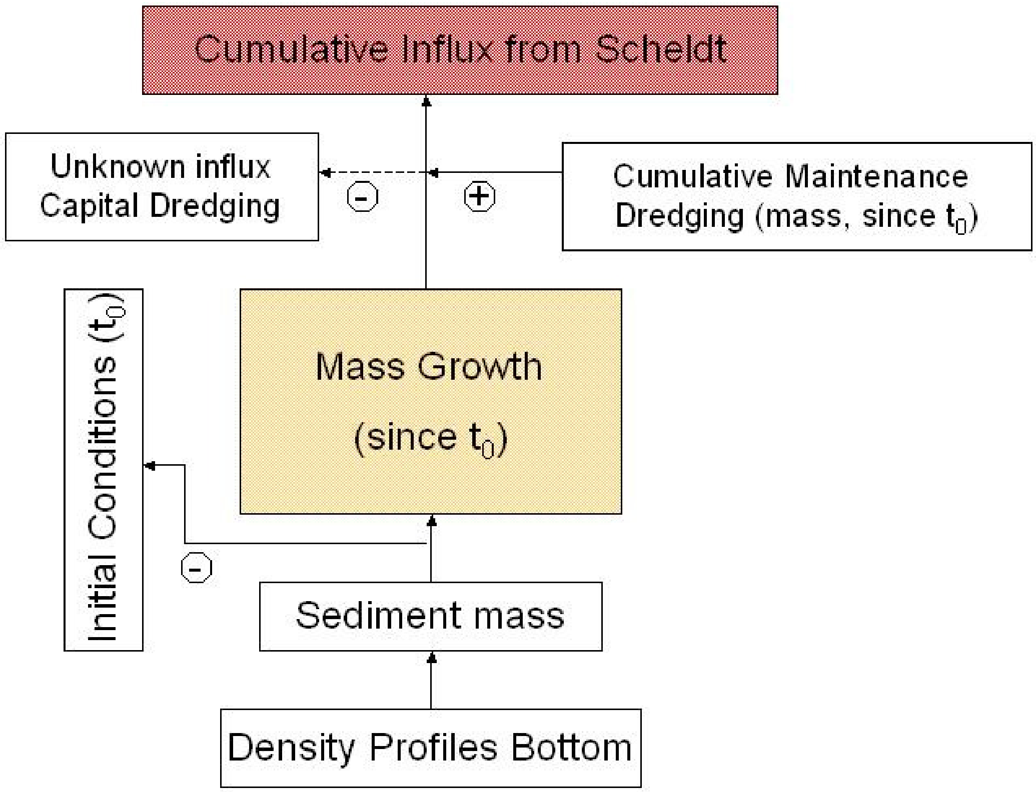

Figure 2-3: Determining a sediment balance

The main purpose of the second part of the study is to gain insight in the mechanisms causing siltation in Deurganckdok. The following mechanisms will be aimed at in this part of the study:

- Tidal prism, i.e. the extra volume in a water body due to high tide
- Vortex patterns due to passing tidal current
- Density currents due to salinity gradient between the Scheldt river and the dock
- Density currents due to highly concentrated benthic suspensions

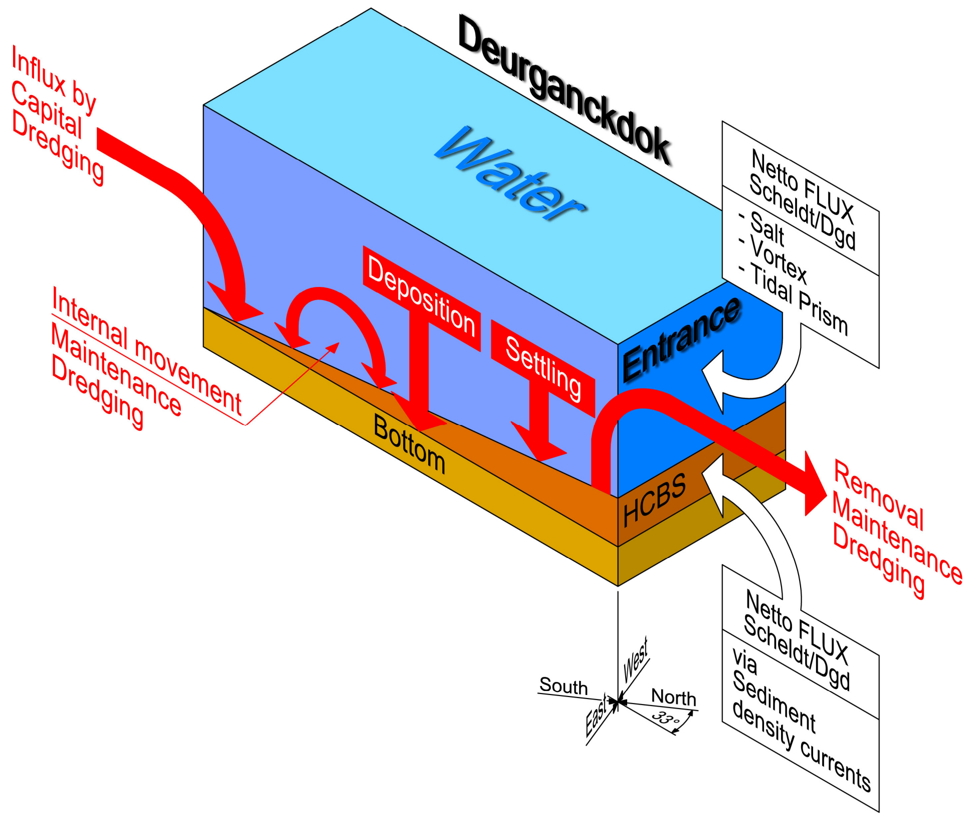

Figure 2-4: Transport mechanisms

These aspects of hydrodynamics and sediment transport determine the parameters to be measured during the project. Measurements will be focused on three types of timescales: one tidal cycle, one neap-spring cycle and seasonal variation within one year.

Following data are being collected to understand these mechanisms:

- Monitoring upstream discharge in the Scheldt river.
- Monitoring salinity and sediment concentration in the Lower Sea Scheldt at permanent measurement locations at Oosterweel, up- and downstream of the Deurganckdok.
- Long term measurement of salinity and suspended sediment distribution in Deurganckdok.
- Monitoring near-bed processes (current velocity, turbidity, and bed elevation variations) in the central trench in the dock, near the entrance as well as near the current deflecting wall location.
- Dynamic measurements of current, salinity and sediment transport at the entrance of Deurganckdok.
- Through tide measurements of vertical sediment concentration profiles -including near bed high concentrated benthic suspensions.
- Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks as well as dredging and dumping activities in the Lower Sea Scheldt.
- In situ calibrations were conducted on several dates to calibrate all turbidity and conductivity sensors.

3. MEASUREMENTS

3.1. Depth soundings

The client executed dual-frequency echo-sounder measurements every week to every three weeks with a 210-33 kC Echo sounder using the Qinsy software. The depth sounding measurements were executed in a grid configuration, consisting of sections perpendicular and parallel to the quay wall.

Table 3-1: Overview of available good-quality depth soundings suitable for analysis: 01/04/2006 – 31/03/2007

date	*type of measurement*	*signal*	*Source*
24/03/2006*	dual frequency 210-33 kHz	210	Afdeling Kust
14/04/2006	dual frequency 210-33 kHz	210	Afdeling Kust
21/04/2006	dual frequency 210-33 kHz	210	Afdeling Kust
28/04/2006	dual frequency 210-33 kHz	210	Afdeling Kust
12/05/2006	dual frequency 210-33 kHz	210	Afdeling Kust
26/05/2006	dual frequency 210-33 kHz	210	Afdeling Kust
9/06/2006	dual frequency 210-33 kHz	210	Afdeling Kust
30/06/2006	dual frequency 210-33 kHz	210	Afdeling Kust
7/07/2006	dual frequency 210-33 kHz	210	Afdeling Kust
27/07/2006	dual frequency 210-33 kHz	multibeam	Afdeling Kust
4/08/2006	dual frequency 210-33 kHz	210	Afdeling Kust
7/08/2006	dual frequency 210-33 kHz	210	Afdeling Kust
1/09/2006	dual frequency 210-33 kHz	210	Afdeling Kust
21/09/2006	dual frequency 210-33 kHz	210	Afdeling Kust
23/10/2006	dual frequency 210-33 kHz	210	Afdeling Kust
8/12/2006	dual frequency 210-33 kHz	210	Afdeling Kust
09/02/2007	dual frequency 210-33 kHz	210	Afdeling Kust
09/03/2007	dual frequency 210-33 kHz	210	Afdeling Kust

*= reference situation depth soundings: t_{0e}

To calculate a sediment balance it is preferred to analyse the measurements in stationary conditions, with no alteration in boundary conditions being dredging operations. Every period is characterised by a depth sounding measurement before ('inpeiling') and one after ('uitpeiling') dredging.

A number of analyses were done using the depth soundings in Table 3-1. The raw depth sounding data was processed in ESRI ArcGIS. Only the 210 kC signal is used in the following analyses as it gives an indication of the water-bed interface.

A reference level was chosen from all depth sounding measurements, effectively the earliest most complete measurement. This turned out to be the measurement on 24 March 2006. This will be considered as a reference situation, initial condition t_{0e} (subscript 'e' refers to echo-sounder).

A number of analyses were performed in ArcGIS 9 and a Matlab environment to produce maps, figures and tables with relevant information concerning elevation, elevation changes and volumetric growth (§4.2 to §4.4).

3.2. Density measurements

The Navitracker was used to perform density measurements. Density measurements are necessary to calculate a sediment balance of dry weight of sediment per surface unit.

The Navitracker is a patented system to measure the density of fluid mud suspensions by means of a gamma-density meter. It has been used by the Flemish authorities for 20 years to determine the nautical bed for the port of Zeebrugge.

The Navitracker system can be operated by a computer controlled winch to tow it through the mud (horizontal mode). The Navitracker is equipped with the following sensors:

- The Gamma ray density sensor, mounted on a fork-like tow fish, gives density information.
- The depth sensor gives information of the depth of the sensor.
- The position of the fish is calculated out of the length of the winch cable. Together with the position of the tow fish, following the density level, a dual frequency echo sounder is used to map the hard bottom and the top of the mud. With a speed of 2 to 3 knots, large areas can be covered.

For these measurements the Navitracker was used in a vertical profiling mode, with the probe in vertical position in order to penetrate the soft bottom. The vertical density profiler is used to measure density in thick mud layers with high densities.

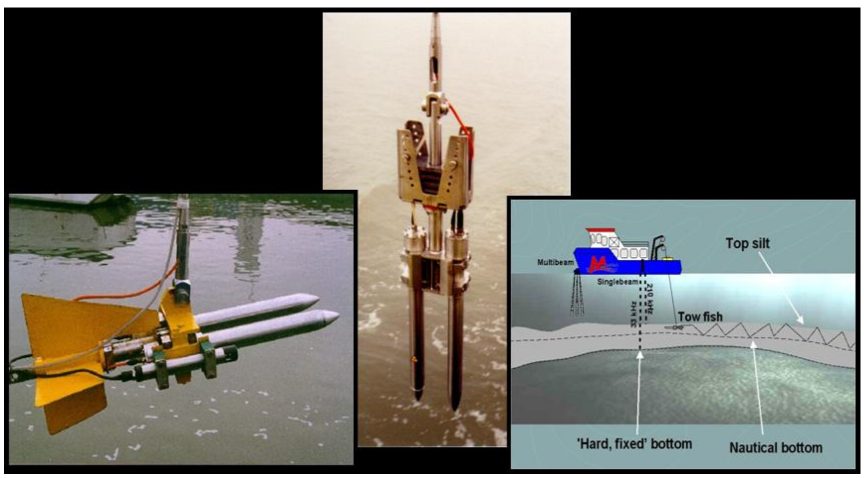

Figure 3-1: Navitracker

The Navitracker was calibrated in the laboratory for measuring high densities, formed by very dense water-mud mixtures. For this reason the Navitracker did not detect subtle variations in density caused by changes in salinity. The density deviated from 1.000 ton/m³ only in the presence of a high concentration of sediments.

The Navitracker has a sampling frequency of 10 measurements per second.

As a reference situation, t_{0d} (subscript 'd' refers to density), the empty dock will be used at the design depth. The design depths for the different zones are shown in Table 3-3. The different zones are described in §4.1.

The resulting profiles were processed in a Matlab environment and visualized in Matlab and ESRI ArcGIS. Equal density layers were computed. Volume and density information was used to calculate masses of silt. All masses are given in tons of dry solids (TDS) characterised by a density of 2.65 kg/dm³. The water-bed interface is defined as the layer with a density of 1.03 kg/dm³.

During this 12-month period, only one density measurement took place on 19/09/2006 (APPENDIX D).

Table 3-3: Reference Situation Density Measurements (t_{0d})

Zone	Design Depth (mTAW)
Central trench	-19
Berthing zones and transition zones to central trench	-17
Sill	-13.5
Transition sill to navigation channel	Not applicable

3.3. Maintenance Dredging Data

All maintenance dredging (except sweep beam) activities in Deurganckdok were registered in the BIS-system. This system gives a standardised output per week, that states the weight, volume and V'[1] removed/dumped in every 5*5 m grid cell in the area. In case the density of the dredged sediment in the hopper bin is larger or equal to 1.6 kg/dm³, V' is equal to the volume in the bin. In case the density is smaller than 1.6 kg/dm³, V' is equal to the reduced volume which is defined as the volume the dredged sediment would have in case the density would be equal to 2 kg/dm³ (AWZ 2000). These dredged volumes are important to have an overall view on the sediment balance.

An overview of the total dredged mass in all zones (BIS data) is provided in APPENDIX E.

The available data on sweep beam activities is not collected in the BIS-system. However, the mode of operation of the sweep beam is registered as follows:

- on the sill (zone 1 & 2): the sediment is moved into the Lower Sea Scheldt
- inside the dock: the sweep beam sweeps the berthing zones next to the quay walls and moves sediment into the central trench

Table 3-5 gives an overview of where and when the sweep beam dredger was working in the Deurganckdok (DGD) or on the sill of Deurganckdok (sill DGD). For the period January-March 2007, sweep beam tracks were available from Afdeling Maritieme Toegang. Unfortunately, the data quality (IMDC, 2007d) restricts its applicability to a rough estimate of the sweep beam location.

Table 3-5: Sweep beam maintenance dredging activities in Deurganckdok and on the sill of Deurganckdok between 1 April 2006 and 31 March 2007 (source: Afdeling Maritieme Toegang)

From	Till	Duration (days)	Location
3/4/2006	3/4/2006	1	Sill DGD
10/4/2006	10/4/2006	1	Sill DGD
18/4/2006	22/4/2006	5	DGD+ Zandvliet Container Dock
24/4/2006	24/4/2006	1	Sill DGD
2/5/2006	6/5/2006	5	DGD
8/5/2006	13/5/2006	5	Sill DGD
15/5/2006	15/5/2006	1	DGD+Sill DGD
22/5/2006	22/5/2006	1	Sill DGD
29/5/2006	29/5/2006	1	Sill DGD

[1] V' = Reduced Volume

From	***Till***	***Duration (days)***	***Location***
30/05/2006	3/6/2006	5	DGD commercial quays
6/6/2006	6/6/2006	1	Sill DGD
7/6/2006	8/6/2006	1	DGD commercial quays
12/6/2006	12/6/2006	1	Sill DGD
13/6/2006	17/6/2006	5	DGD commercial quays
19/6/2006	19/06/2006	1	Sill DGD
26/6/2006	26/6/2006	1	Sill DGD
3/7/2006	3/7/2006	1	Sill DGD
3/7/2006	8/7/2006	6	DGD + Europaterminal
10/7/2006	10/7/2006	1	Sill DGD
17/7/2006	17/7/2006	1	Sill DGD
24/7/2006	24/7/2006	1	Sill DGD
25/7/2006	29/7/2006	5	DGD
31/7/2006	31/07/2006	1	Sill DGD
7/8/2006	7/8/2006	1	Sill DGD
16/8/2006	16/8/2006	1	Sill DGD
21/8/2006	21/8/2006	1	Sill DGD
28/8/2006	28/8/2006	1	Sill DGD
4/9/2006	4/9/2006	1	Sill DGD
11/9/2006	11/9/2006	1	Sill DGD
18/9/2006	18/9/2006	1	Sill DGD
25/9/2007	25/9/2007	1	Sill DGD
2/10/2006	2/10/2006	1	Sill DGD
9/10/2006	9/10/2006	1	Sill DGD
10/10/2006	14/10/2006	5	DGD
13/11/2006	13/11/2006	1	Sill DGD
20/11/2006	20/11/2006	1	Sill DGD
27/11/2006	27/11/2006	1	Sill DGD
4/12/2006	4/12/2006	1	Sill DGD
11/12/2006	11/12/2006	1	Sill DGD
18/12/2006	18/12/2006	1	Sill DGD
16/01/2007	16/01/2007	1	Sill DGD
8/01/2007	8/01/2007	1	Sill DGD
22/01/2007	22/01/2007	1	Sill DGD
29/01/2007	29/01/2007	1	Sill DGD
05/02/2007	05/02/2007	1	Sill DGD
12/02/2007	12/02/2007	1	Sill DGD
19/02/2007	19/02/2007	1	Sill DGD
26/02/2007	4/03/2007	5	Sill DGD + DGD
27/02/2007	27/02/2007	1	Sill DGD + DGD
5/3/2007	11/3/2007	5	Sill DGD + DGD
12/03/2007	12/03/2007	1	Sill DGD
19/03/2007	19/03/2007	1	Sill DGD
26/3/2007	26/3/2007	1	Sill DGD

3.4. Overview of activities and processes

To facilitate the data analysis in Chapter 5, Table 3-7 gives an overview of all conducted measurements and human interferences on the natural siltation in the dock. This makes it possible to identify periods of undisturbed siltation of specific zones in the dock. The period between November and Mid-February is indeed characterised by the absence of any maintenance dredging and sweep beam activity inside the dock. Capital dredging occurred early 2007 at the backside of the dock, being outside the study area. Suspended sediment plumes are expected being negligible. Therefore, these months can be seen as an ideal period to study naturally occurring siltation processes. Obviously, not only the entire dock area but specific areas inside the dock can be isolated too for further investigation. This is made possible by the time-series' results shown in Chapter 4.

Table 3-7: Overview of measurements and dredging activities in the Deurganckdok

	March 06	April 06		May 06		June 06		July 06		August 06		September 06	
activity	**16 - 31**	**1 - 15**	**16 - 30**	**1 - 15**	**16 - 31**	**1 - 15**	**16 - 30**	**1 - 15**	**16 - 31**	**1 - 15**	**16 - 31**	**1 - 15**	**16 - 30**
depth sounding													
density measurements													
maintenance dredging													
sweep beam dredging - sill													
sweep beam dredging - commercial quays													
capital dredging													

	October 06		November 06		December 06		January 07		February 07		March 07	
activity	**1 - 15**	**16 - 31**	**1 - 15**	**16 - 30**	**1 - 15**	**16 - 31**	**1 - 15**	**16 - 31**	**1 - 15**	**16 - 28**	**1 - 15**	**16 - 31**
depth sounding												
density measurements												
maintenance dredging												
sweep beam dredging - sill												
sweep beam dredging - commercial quays												
capital dredging												

4. SEDIMENT BALANCE ANALYSES

4.1. Project Area: (Sub)Zones and Sections

To calculate volumes and masses for the sediment balance of Deurganckdok it is necessary to subdivide it into 5 zones:

- Zone 1: Between the sill and the navigation channel in the Lower Sea Scheldt.
- Zone 2: Sill at entrance DGD designed at –13.5 m TAW.
- Zone 3: Central trench in DGD with a design depth at –19 m TAW (including slope to –17 m TAW)
- Zone 4: Transition between central trench and berthing zones with a design depth at –17.00 m TAW: on both (North (N) and South (Z)) sides of DGD (55 m wide).
- Zone 5: Berthing zones next to quay walls on both (North (N) and South (Z)) sides of DGD (40 m wide)

Zones 3, 4 and 5 are subdivided into subzones A, B and C. This is shown in Figure 4-1.

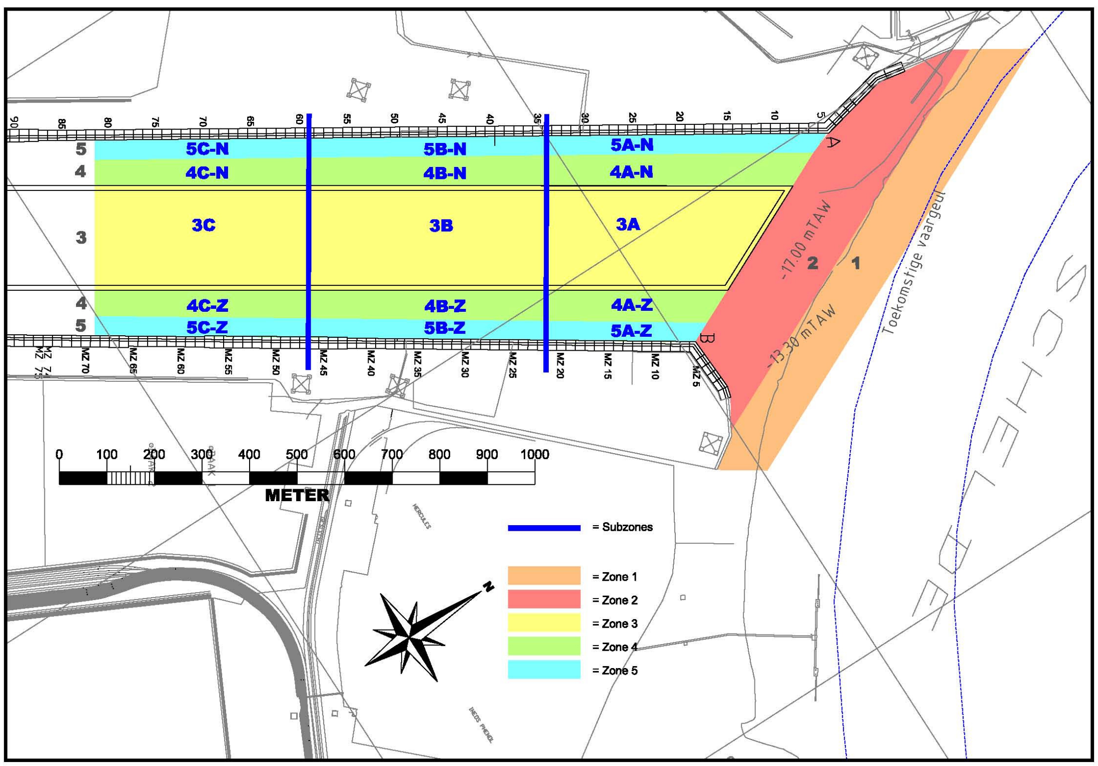

Figure 4-1: Deurganckdok: Zones and Subzones

Sections are defined for this whole area (Figure 4-2):

- D sections are oriented perpendicular to the quay walls inside the dock and parallel to the navigation channel outside the dock (sill and Scheldt). The origin of the sections is taken on the quay wall at the left bank (West side) looking outwards.

- L Sections are oriented along the centerline of the dock and run from the navigation channel towards the inland end of the dock, in anticipation of the realisation of the third phase of Deurganckdok. The origin is situated on the intersection between each L section and section D10.

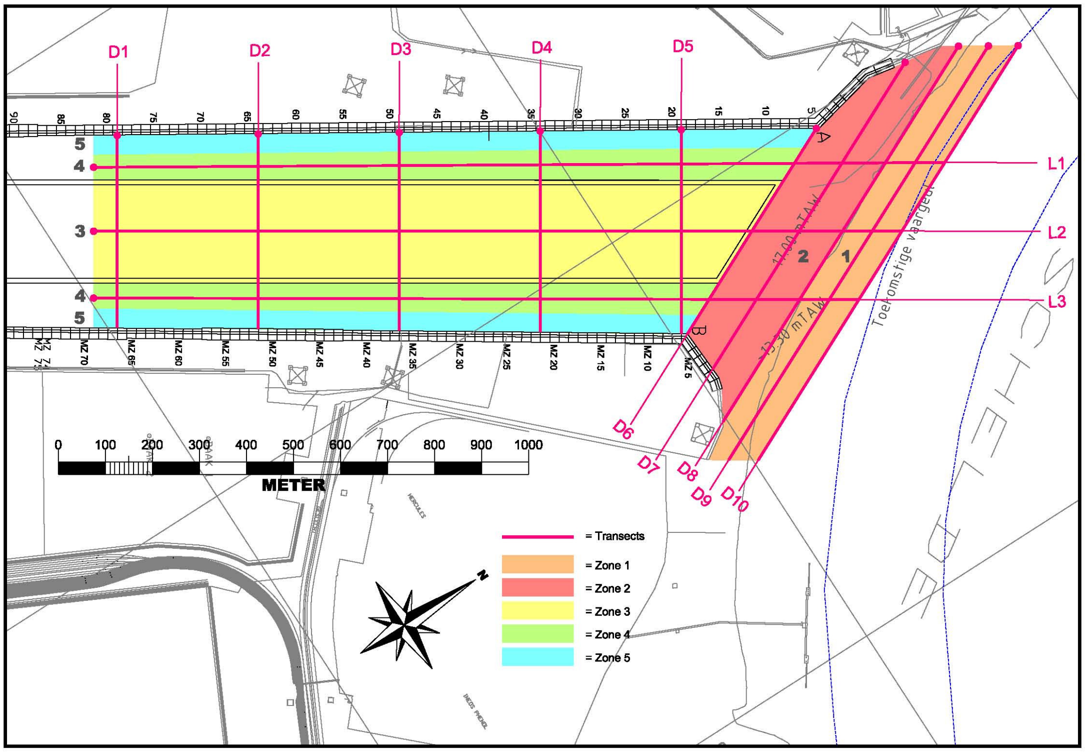

Figure 4-2: Deurganckdok: D and L Sections

The coordinates of these sections are given in Table 4-1.

Table 4-1: Coordinates of Sections [UTM ED50]

Name	***Origin***		***End***	
	Easting	***Northing***	***Easting***	***Northing***
D Sections				
D1	587773	5683253	588123	5683037
D2	587929	5683510	588283	5683290
D3	588084	5683767	588444	5683544
D4	588239	5684023	588604	5683797
D5	588394	5684280	588765	5684051
D6	588542	5684526	588772	5684062
D7	588521	5684761	588864	5684068
D8	588552	5684875	588972	5684027
D9	588585	5684930	589047	5683994
D10	588617	5684984	589081	5684047
L Sections				
L1	588748	5684720	587805	5683175
L2	588825	5684565	587921	5683103
L3	588901	5684410	588043	5683028

4.2. Depth of the water-bed interface (210 kC)

This is shown as a GIS grid map generated directly from the depth sounding data. The initial and final bathymetries are shown in Figure 4-3, and the enlarged format can be found in APPENDIX A. Only these depth soundings are considered in this report because the annual trend is aimed at. All other collected depth sounding dataset can be found in IMDC(2007a,b,c,d).

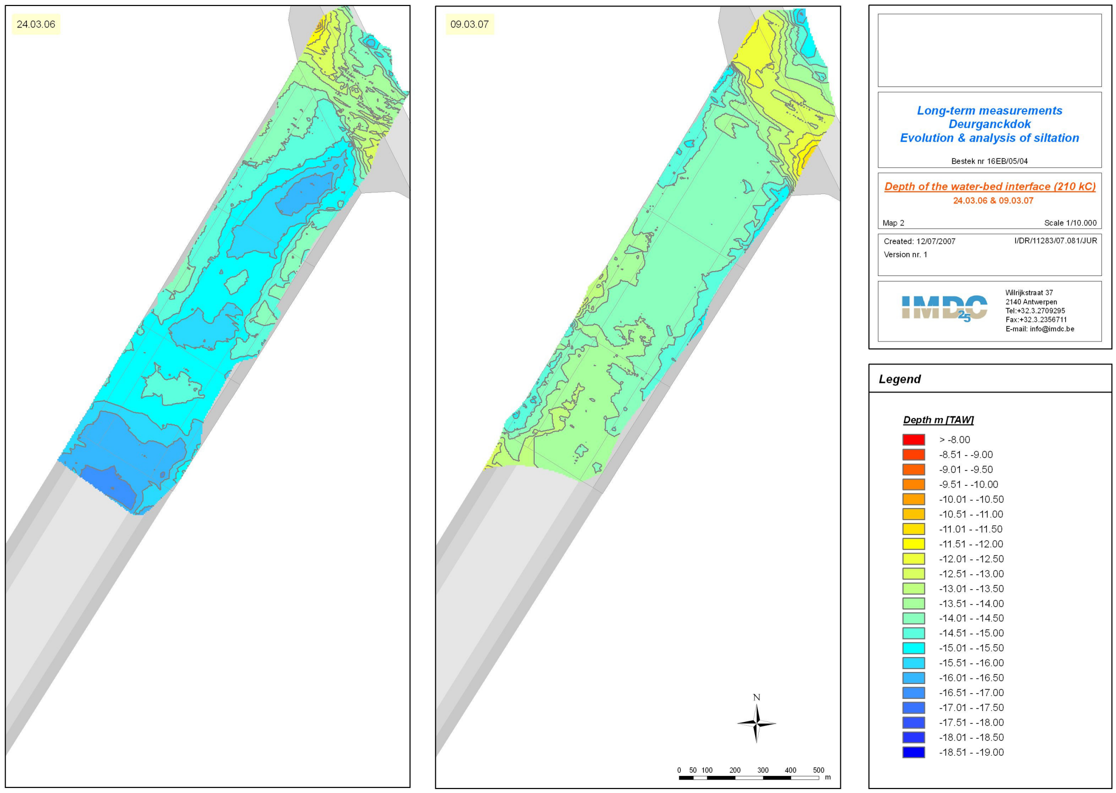

Figure 4-3: Depth of water-bed interface (210 kHz) for 24/03/06 (t_{0e}) and 9/03/07

4.3. Evolution of water-bed interface (210 kC)

GIS grid maps show the difference charts for every depth sounding in relation to the reference situation (t_{0e}). Figure 4-4 shows such a difference chart covering the period of one year. Note that intermediate difference charts can be found in IMDC(2007a,b,c,d).

The difference in depth between subsequent depth soundings for 210 kC measurements is also calculated for all predefined sections. Graphs show a colour plot with Time in the X-axis, Distance to origin of section in the Y-axis and the depth of the top layer [m TAW] as a colour plot.

The origin for de the D sections is the northern quay wall. The origin of the L sections is the intersection between the L section with the Scheldt edge of zone 1. An example for sections is shown in Figure 4-5. The description of the sections is given in § 4.1.

Maps and graphs are shown in APPENDIX B.

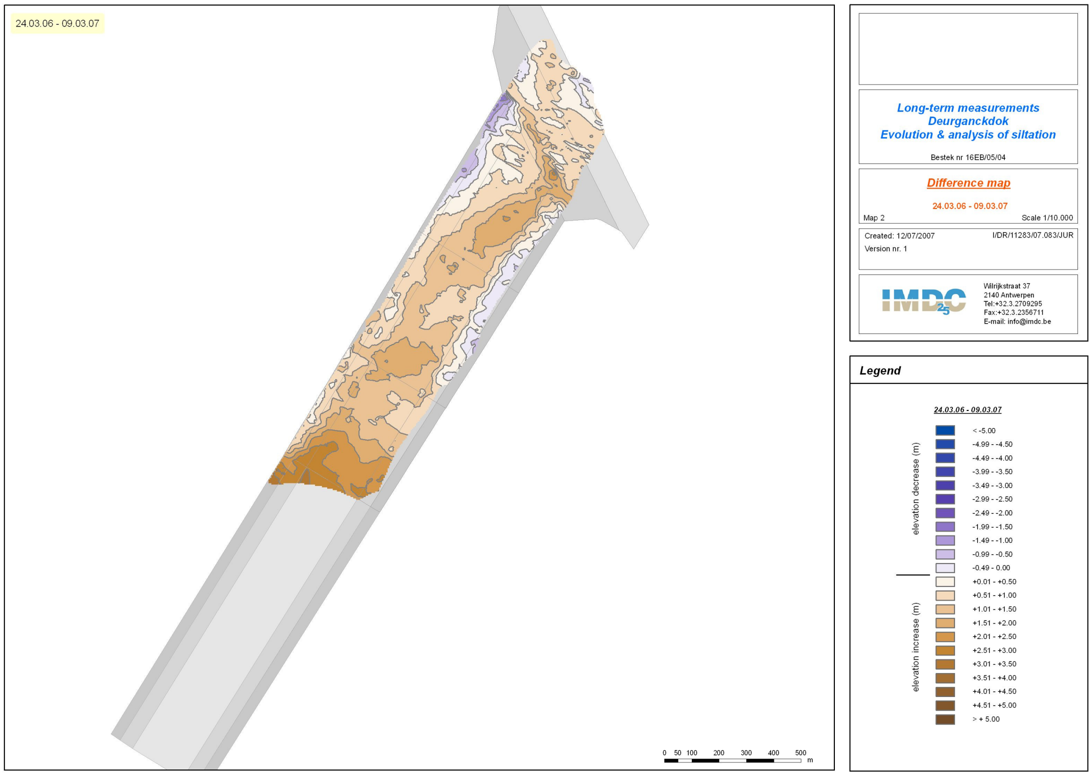

Figure 4-4: Difference charts of the depth sounding on 9/03/07 in reference to t_{0e}

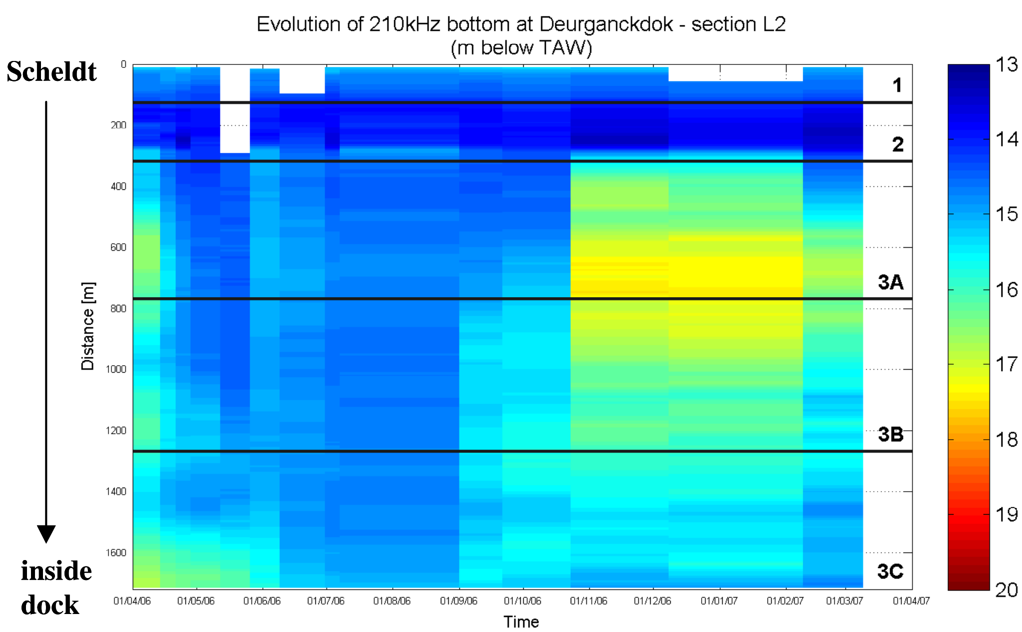

Figure 4-5: Graph of evolution of the water-bed interface (210 kHz) for section L2

4.4. Volumetric siltation rates [cm/day] in different zones and sections

A table with gross siltation rates for all (sub)zones is also given in APPENDIX C.

Graphs in APPENDIX C show two parameters:

- Gross siltation rates [cm/day]: The gross siltation rate is the difference in the depth of the water-bed interface and is calculated only for those zones and subzones that have at least a 50% surface area overlap between two subsequent depth soundings. This is done for all successive depth soundings. It is shown in the plots as a bar and is positive for sedimentation and negative for erosion or sediment removal.
- Cumulative bed level change [m]: an initial situation (t_{0e}) is used as baseline. Starting from this reference level the evolution of the average bed level elevation is shown for the particular (sub)zone.

Dredging events from the BIS system are marked on each of these graphs. This is computed for all zones, subzones, sections and Deurganckdok as a whole. As an example, the siltation rate and cumulative bed level change for zone 3a are shown in Figure 4-6.

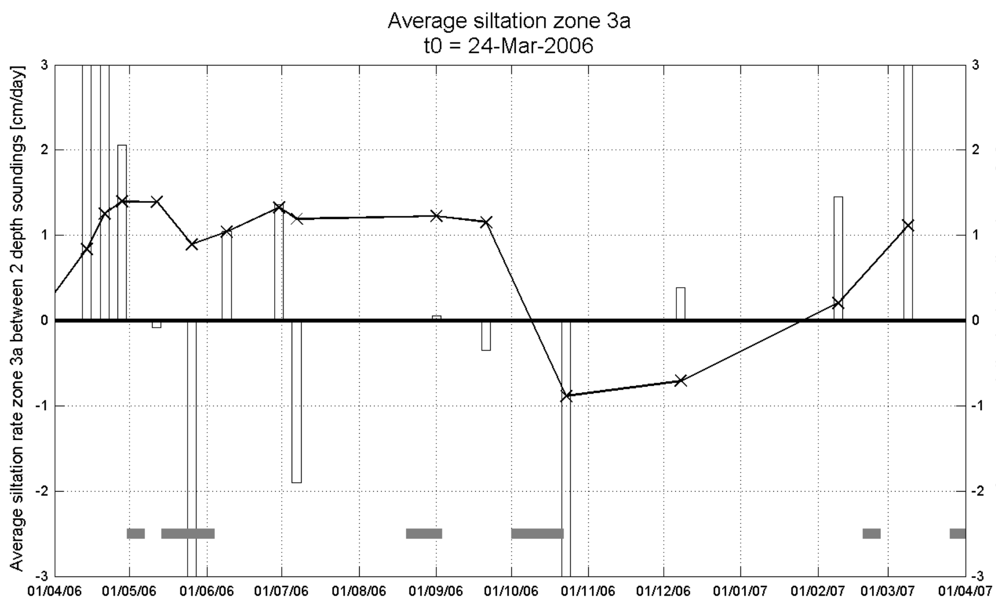

Figure 4-6: Volumetric siltation rate for zone 3a

5. DATA ANALYSIS

5.1. Introduction

This chapter discusses the measurements on a yearly basis. Three-monthly trends that are already covered in previous reports are not dealt with, cf. IMDC (2007a,b,c,d). Instead, more long-term evolutions are focused, or evolutions and phenomena bridging these three-monthly periods.

With respect to the data analysis and its interpretation, it is important to keep in mind the different contributing terms in the sediment mass balance of each defined zone in the Deurganckdok:

$$\frac{dM_s}{dt} = R_{siltation} - R_{erosion} \pm R_{sweepbeam} - R_{maintenance} \pm R_{capitaldredging}$$

with:

- M_s = local amount of sediment mass [TDS]
- $R_{siltation}$ = sediment mass flux from siltation [TDS/day]
- $R_{erosion}$ = sediment erosive flux [TDS/day]
- $R_{sweepbeam}$ = mass flux from sweep beam dredging operations [TDS/day]
- $R_{maintenance}$ = mass flux from maintenance dredging [TDS/day]
- $R_{capital\ dredging}$ = mass flux from capital dredging [TDS/day]

It is important to note that observations of bed level changes (from depth soundings) refer to the gross effect of all contributing terms. Strictly seen, the siltation rate is only observed when no other process takes place at a specific location. With respect to the erosive flux, it is expected that flow velocities and shear forces are so low that erosion can be neglected from the mass balance.

Note that further issues related to the sediment balance are dealt with in Chapter 6.

In this report, the 'volumetric siltation rate' is computed from the temporal bed level change as obtained from the depth soundings. Because different processes result in these observations, it is crucial to understand what is meant by the computed 'volumetric siltation rate'. For that reason, some definitions are considered important for the data interpretation:

- natural siltation rate: is computed from a time period in which only siltation occurs and no other process;
- gross siltation rate: is computed from a time period in which other processes occur besides the natural siltation;

The difference between these two definitions is schematised in Figure 5-1. Note that the gross siltation rate may also be larger than the natural one due to e.g. sweep beam activities, which may import sediment into the considered dock zone.

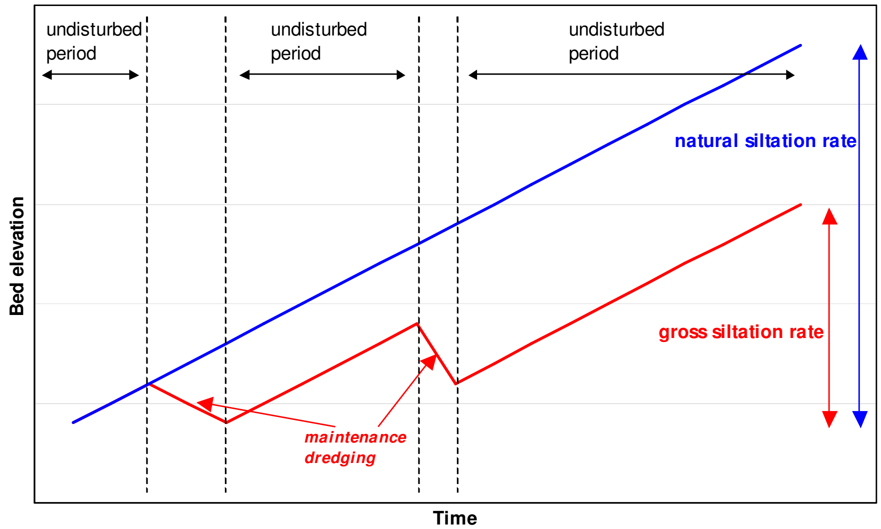

Figure 5-1: difference between natural and gross siltation rate

Seen the nature of collected data and their relation to the sediment balance, the chapter below will discuss the following topics:

- changes in elevation of the water-bed interface, i.e. the volumetric siltation rate;
- the accumulation of sediment mass in the dock; and
- the dredged sediment mass.

5.2. Volumetric siltation rates

Depth sounding data was processed to show the evolution of the bed level as detected by the 210 kHz sounder. If more than 50% of the area of a (sub)zone was covered, an average bed level change was calculated. On average, two bathymetric measurements per month were performed in 2006. Data was missing for January 2007. With respect to February and March 2007, each month showed only one measurement.
For the entire measurement period, no adequate coverage was obtained during depth soundings for zones 1, 5A-Z, 5B-Z and 5C-Z. Additionally, zones 4C-Z, 5A-N and 5B-N were not adequately covered in the months of March and April 2006.

Below, the natural and the gross yearly averaged siltation rates are discussed.

5.2.1. Gross yearly averaged siltation rate

To compute a gross yearly averaged siltation rate for every zone of the dock, the raw depth soundings are used because monthly averaged values may entail too large estimation errors. This is inherent to the way the monthly estimates were computed. Here, the subsequent bed level measurements are used to compute the gross siltation rate. This gross siltation rate is valid for the time period between these subsequent depth soundings. As a consequence, effects from dredging activities are included in these results. The obtained siltation rates therefore refer to a *gross* yearly

averaged siltation rate. The results are shown in Table 5-1, which indicates that zones exist with a gross siltation rate of more than one cm per day, i.e. zones 3A, 3B, 3C, 4N-C and 4Z-C. Gross yearly averaged siltation rates between 1.1 and 1.7 cm/day prevail here.
One zone can be identified with a negative siltation rate, i.e. zone 5N-A, which is located at the north side of the dock entrance. This area is largely subjected to local siltation. The authorities perform intense sweep beam and maintenance dredging in this area. Hence, a large variation in bed levels can be observed over the one-year period (see APPENDIX C).

Table 5-1: gross yearly averaged siltation rates for every zone

ZONE	gross yearly averaged siltation rate [cm/day]
2	0.75
3a	1.12
3b	1.22
3c	1.68
4Na	0.22
4Nb	0.83
4Nc	1.51
4Za	0.36
4Zb	0.14
4Zc	1.56
5Na	-0.31
5Nb	0.63
5Nc	0.33
5Za	0.95
5Zc	0.89

When investigating the entire dock, it could be computed that the bed level, measured by the 210 kHz depth soundings, increased with 0.2 cm/day. For the 350 days of investigation, this results in a total spatially averaged bed level increase of around 67 cm. This is smaller than shown in APPENDIX C.4 where a value of around 80 cm is presented. The latter is computed from the difference between the final and initial bed level measurement (of the one-year measurement period), whereas the former is calculated from the consecutive depth soundings. However, differences in zone coverages between these soundings finally result in the discrepancies mentioned above. It is clear that a gross (positive) siltation rate occurs in the Deurganckdok.

5.2.2. Natural siltation rate

The observed siltation rates are the result of many processes of which the natural siltation is only one. Human interferences such as maintenance and sweep beam dredging indeed largely influence the sediment balance of the dock. Whereas the maintenance dredging removes sediment from the dock, sweep beam dredging along the quays simply relocates the sediment towards the central trench (where it is removed by a subsequent maintenance dredging operation).

Quantifying the natural siltation is important as it determines the necessary dredging frequency. To do so, it is essential to identify undisturbed periods where no human interferences took place. From the observed bed elevation trend during such a period, the natural siltation rate can be calculated. Remark that siltation rates depend on local bathymetric and hydrodynamic conditions. Hence, it is important to acknowledge that calculated siltation rates cannot be generalised.

However, the calculations return an order of magnitude for the siltation rates and allow the investigation of any spatial distribution of this process variable.

When investigating the siltation in zones A and B (cf. APPENDIX C.4), two periods can be identified being undisturbed by maintenance dredging, i.e.

- 23/3/2006 – 28/4/2006; and
- 23/10/2006 – 9/2/2007.

However, the computed siltation rate on 21/4/2006 is artificially increased by intense sweep beam activities. The first period is therefore excluded from the analysis. Therefore, only the second period will be used for the analysis. An average siltation rate of 0.98 cm/day is computed for the period 23/10/2006 – 9/2/2007.
Similarly, the siltation rate can be computed for each zone separately. Zones 1 and 2 are not considered here as no measurements are available for the former zone, and frequent sweep beam dredging in zone 2 makes it hard to analyse the local natural siltation rate. Also zones 5Nb and 5Zb are inadequate.
For all other zones, the natural siltation rate could be determined on the basis of undisturbed measurement periods. These periods differ for each zone because dredging activities did not take place everywhere at the same time. The obtained natural siltation rate values are shown in Table 5-3. Note that the natural siltation rate measured for zone 4Za is doubtful seen the small negative rate on 8/12/2006 at which no human interferences were registered. However, sweep beam dredging occurred on the sill and, maybe, accidentally moved some sediment away from the neighbouring zone 4Za.

5.2.3. Natural vs. gross siltation rate

Comparing Table 5-1 with Table 5-3 reveals that the natural siltation rate may be larger or smaller than the gross yearly averaged siltation rate. The natural siltation rate in the central trench will be smaller than the gross siltation rate due to sweep beam dredging operations. The sweep beam moves sediment from the quay walls into the central trench and thus artificially increasing the siltation rate. Zones 4Nc and 4Zc show a similar behaviour with respect to siltation rates but the cause is unknown (no registered sweep beam actions).

Table 5-3 also clearly indicates that zones 4Na and 5Na are very sensitive to siltation. These zones generally show natural siltation rates being double of the other zones. Interesting to note is the fact that, in the central trench of the dock, siltation decreases when going further into the dock, away from the Scheldt. Although some data is missing, the general trend is that the northern berthing zones, and associated transition zones, show larger siltation rates in comparison to the southern ones. Although these zones are more susceptible to siltation, twice as much mass had been dredged from the northern quays in comparison to the southern ones (see APPENDIX E).

In 2004, sediment transport simulations of the Deurganckdok were performed in order to investigate natural siltation rates (IMDC, 2004). The applied mathematical model indicated that the first one third of the dock, near the Scheldt, was characterised with a siltation rate of 1.4 cm/day and decreased when going more inside the dock. This spatial trend of siltation rates inside the dock is similar to the present observations.

Further, the hydrodynamic sediment transport model returned an estimation of the sedimentation volume to be dredged annually. It measured approximately 4.3 million m^3/year if the sediment is dredged immediately (at a bulk density of around 1.15 kg/l) after sedimentation. This results in an area-averaged mean volume of 3.4 m^3/m^2.year to be dredged. The actual observations return a value of 2.9 m^3/m^2.year.

Obviously, the absolute values differ because of model assumptions, e.g. the fully constructed dock was considered in the simulations whereas the observations are related to a partly constructed dock. Clearly, an absolute comparison between the simulation study and the actual measurements is not applicable. However, the order of magnitude and the trends are similar.

Table 5-3: natural siltation rates obtained from undisturbed measurement periods

	natural siltation rates [cm/day]			
ZONE	8/12/06 – 9/2/07	8/12/06 – 9/3/07	9/2/07	9/2/07 – 9/3/07
3a	1.00			
3b	0.65			
3c	0.37			
4Na	1.62			
4Nb	0.88			
4Nc				0.8
4Za	0.26			
4Zb	0.62			
4Zc		0.61		
5Na			1.68	
5Nc			0.73	
5Za	0.51			

5.2.4. Remarks

Finally, two remarks are made on the siltation in the period between 8/12/06 and 9/2/2007:

- From the bathymetric maps, it was observed that a depression from maintenance dredging works occurred in zone 3a and a part of zone 3b. This depression acted as a sediment trap resulting in increased siltation rates for zone 3a, i.e. a rate of 0.39 cm/day whereas zone 3b only showed a small rate of 0.03 cm/day. This difference of 92% largely diminished when the depression was shallower by the time of the measurement of 9/2/2007. Suspended sediment was less trapped and the difference in siltation rate now only measured 23%.
- Remark also that the bed elevation increase, and as a consequence the siltation rate too, showed an increasing trend. Simulations (IMDC, 2004) indeed indicated that siltation rates become larger at shallower water. However, a possible changing influx from the Scheldt may be the cause too. Such influences are investigated in Report 4.1 “Analysis of Siltation Processes and Factors” (I/RA/11283/06.129/MSA).

5.3. Accumulation of sediment mass

The volumetric siltation rate, computed from 210 kHz depth sounding profiles, does not reveal the amount of mass that settles. Information on the consolidation process remains unknown too.

In this respect, density measurements with the Navitracker give important information. Unfortunately, only one measurement was conducted on 20/9/2006, which resulted in a mean accumulated sediment mass of 1.23 TDS/m², i.e. the total sediment mass accumulated on top of the design depth of Deurganckdok. Compared to the previous density measurement on 3/12/2005 (see IMDC, 2006a), this means an increase of 0.2 TDS/m² over a period of nine months.

5.4. Dredged sediment mass

From the BIS data (see APPENDIX E), it can be concluded that more than 660,000 TDS was dredged over the entire measurement period (see Table 5-5),. However, some dredging data were missing in the BIS-system. The total dredged mass could be retrieved from the daily dredging reports though, and are included in Table 5-5 too. Accounting for these numbers results in a new total dredged mass of more than 816,000 TDS, being an increase of 23% of the original number. Information about the spatial distribution is however unknown. If hypothesized that the yearly-averaged dredged mass distribution (over the different zones) from the collected BIS-data can be adopted for the new data, total dredged masses can be corrected for the different zones; see Table 5-5.

In the first half of October 2006 (see Table 5-5), 28% of the total amount was dredged. This percentage increased to more than 42% of the total dredged amount when the second half of February 2007 is accounted for as well. These weeks of intense dredging were characterised by dredged masses of more than 100,000 TDS per week. When the geographical distribution of dredged mass in the Deurganckdok is considered, it is observed that more than 59% of the total mass originated from zones 3A and 3B, being the central trench of the dock. Another 24% of the total dredged mass is to be found in zones 3C, 4A-N and 4B-N.
Sweep beam maintenance dredging occurred more frequently. Data loggings show that the dock entrance was swept weekly. Subzones A and B were swept twice in the months April to July 2006. The frequency then lowered to single sweep beam dredging events in October 2006 and February 2007 only.

Table 5-5: Amounts of dredged mass per zone and dredging period

Total dredged mass per week (TDS)														
	30-Apr-06	14-May-06	21-May-06	28-May-06	03-Jul-06	21-Aug-06	28-Aug-06	02-Oct-06	09-Oct-06	16-Oct-06	19-Feb-07	26-Mar-07		
ZONE	07-May-06	21-May-06	28-May-06	04-Jun-06	09-Jul-06	27-Aug-06	03-Sep-06	08-Oct-06	15-Oct-06	22-Oct-06	26-Feb-07	02-Apr-07	Total (TDS)	%
1	1114	0	0	0	43	0	0	0	4	0	0	2	1,163	0.2
2	4873	427	900	1409	4193	0	0	1858	218	0	1305	104	15,287	2.3
3a	8830	12823	15441	19072	9874	79	429	37638	67187	2598	69815	5495	249,281	37.6
3b	5350	14076	13763	18482	11337	5488	8634	18885	30686	69	5574	10211	142,555	21.5
3c	3405	5961	861	5354	54	4782	7608	2710	4199	0	0	7826	42,760	6.5
4Na	4360	59	98	90	13957	93	174	16761	10575	412	17744	1592	65,915	10
4Nb	3194	93	40	653	8796	3879	6927	9045	2147	20	11096	2613	48,503	7.3
4Nc	581	0	0	50	4	3210	1980	1847	132	0	0	1299	9,103	1.4
4Za	4781	4	0	407	11628	24	104	6498	178	6	5957	0	29,587	4.5
4Zb	6960	0	0	0	6722	4980	3167	5239	217	0	5442	0	32,727	4.9
4Zc	1817	0	0	0	0	1650	168	1088	0	0	0	0	4,723	0.7
5Na	400	0	0	0	2478	0	0	3565	3945	80	296	0	10,764	1.6
5Nb	282	0	0	0	1128	224	0	2475	89	0	141	0	4,339	0.7
5Nc	165	0	0	0	0	169	0	764	0	0	0	0	1,098	0.2
5Za	564	0	0	0	550	0	0	435	0	0	0	0	1,549	0.2
5Zb	1035	0	0	0	721	25	0	504	0	0	0	0	2,285	0.3
5Zc	249	0	0	0	0	41	0	414	0	0	0	0	704	0.1
subtotal (TDS)	47960	33444	31103	45517	71485	24643	29192	109726	119576	3183	117370	29142	662,341	
extra data from dredging reports		35899	14837				61059			42066			153,861	
Total (TDS)	47960	69343	45940	45517	71485	24643	90251	109726	119576	45249	117370	29142	816,202	
Total (%)	5.9	8.5	5.6	5.6	8.8	3.0	11.1	13.4	14.7	5.5	14.4	3.6		

Table 5-7: Amounts of dredged mass per zone after correction with daily dredging reports

ZONE	Total (TDS)
1	1632
2	18773

3a	306892
3b	175483
3c	53053
4Na	81620
4Nb	59583
4Nc	11427
4Za	36729
4Zb	39994
4Zc	5713
5Na	13059
5Nb	5713
5Nc	1632
5Za	1632
5Zb	2449
5Zc	816

6. SEDIMENT BALANCE: LIMITATIONS AND RECOMMENDATIONS

As mentioned in Chapter 1, the aim of this study is twofold. Firstly, setting up the sediment balance of the Deurganckdok is focused. Secondly, the mechanisms causing siltation in the dock are to be investigated. The latter is the subject of other reports (see §1.3.1), and the confrontation of both the sediment balance and the siltation contributing factors will be dealt with in Report 4.1 “Analysis of Siltation Processes and Factors” (I/RA/11283/06.129/MSA).

The actual report aims at quantifying the different processes that contribute to the sediment balance in order to compute the sediment influx from the Scheldt. The different contributions are schematically shown in Figure 2-2 and the sediment balance equation is to be found in §5.1. Below, the contributions are discussed in relation to the sediment balance.

6.1. Sweep beam

The sweep beam data (of which no mass or volume information is available) is missing in this mass balance. The sweep beam does not only remove sediments from the sill in the Scheldt, it also relocates sediments inside the dock, cf. sweeping the sediment from the berthing zones to the central trench. As seen from the measurements, it may have a large influence on the internal redistribution of sediment, i.e. from zone to zone. Unfortunately, the lack of good-quality data makes a quantification of this contributing process difficult.

6.2. Maintenance dredging

The BIS database enables the quantification of the sediment removal by the hopper. The volume and weight are measured onboard, but reveals no information on the sediment density though. Although this pragmatic method leads to uncertainties, it enables a gravimetric estimation of the withdrawn sediment.

6.3. Capital dredging

Capital dredging can have an influence on the mass balance by suspending sediment that is not properly removed by the hopper and settles in adjacent zones in the Deurganckdok. However, capital dredging did not occur in 2006; only from February 2007 on, capital dredging was performed. The present dredging performances hardly allow any loss of suspended sediment in the water column. It is therefore assumed that the mass balance would experience a negligible effect from capital dredging activities.

6.4. Settling and consolidation

The settling process is important for the sediment accumulation in the dock because it transports suspended sediment to the bed. A qualitative insight is obtained by the temporal volumetric evolution of the 210 kHz depth soundings. However, the bed dynamics due to consolidation and settling make it extremely difficult to estimate the accumulated sediment mass in certain zones or the entire dock. The local density may indeed change very locally (see APPENDIX D), resulting in large mass estimation errors if unaccounted for. The only appropriate method is to measure, on a regular base, density profiles from which the mass can be computed. This has already been successfully performed in the past (IMDC, 2006a).

6.5. Comments and recommendations

From the discussion above, it is clear that a sediment balance cannot be set up with the available data. Crucial density measurements are missing to set up a sediment mass balance. A sediment balance in volumetric units is only indicative as the same volume may have a different sediment mass content depending on the location and time.

For future sediment balance quantifications, the following recommendations can be made:

- density measurements should be performed on a regular temporal and spatial base; at least just before and after a maintenance dredging operation so the impact of it can be determined;
- depth soundings should be performed before and after maintenance dredging operations so the impact of it can be determined. Frequent soundings in between the dredging operation allow a more accurate follow-up of the siltation process. Depth soundings before and after sweep beam activities inside the Deurganckdok would be crucial to determine any internal sediment movement and explain certain inexplicable observations;
- date and location of sweep beam dredging operations.

7. CONCLUSIONS

The available data consisted mainly of dredging (maintenance and sweep beam) data and depth soundings. Only one density measurement was conducted. Different interesting features, related to siltation, could be identified for the period 24/03/2006 – 09/03/2007:

- the dock showed a gross siltation rate of 0.2 cm/day;
- gross siltation rates of more than 1 cm/day could be observed in the central trench of the dock;
- natural siltation rates inside the dock decrease when moving away from the entrance sill;
- natural siltation results in a volumetric flux of 2.9 m^3/m^2.year.
- the northern berthing zones (4Na, 4Nb, 4Nc and 5Na) show a larger natural siltation compared to the southern zones (4Za, 4Zb, 4Zc and 5Za);
- in total, more than 660,000 TDS was removed over one year, with two periods (first half of October 2006, and second half of February 2007) of intense dredging with withdrawn sediment masses of more than 100,000 TDS per week;
- 59% of all dredged mass originated from zones 3a and 3b.

This report aimed at setting up the annual sediment balance of the Deurganckdok by quantifying all contributing factors such as dredging, sedimentation and sediment accumulation. Unfortunately, this goal could not be reached due to the lack of some crucial data, generally related to sediment mass measurements. In this respect, some important recommendations have been made with respect to future measurements.

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APPENDIX A. DEPTH OF THE WATER-BED INTERFACE (210 KC)

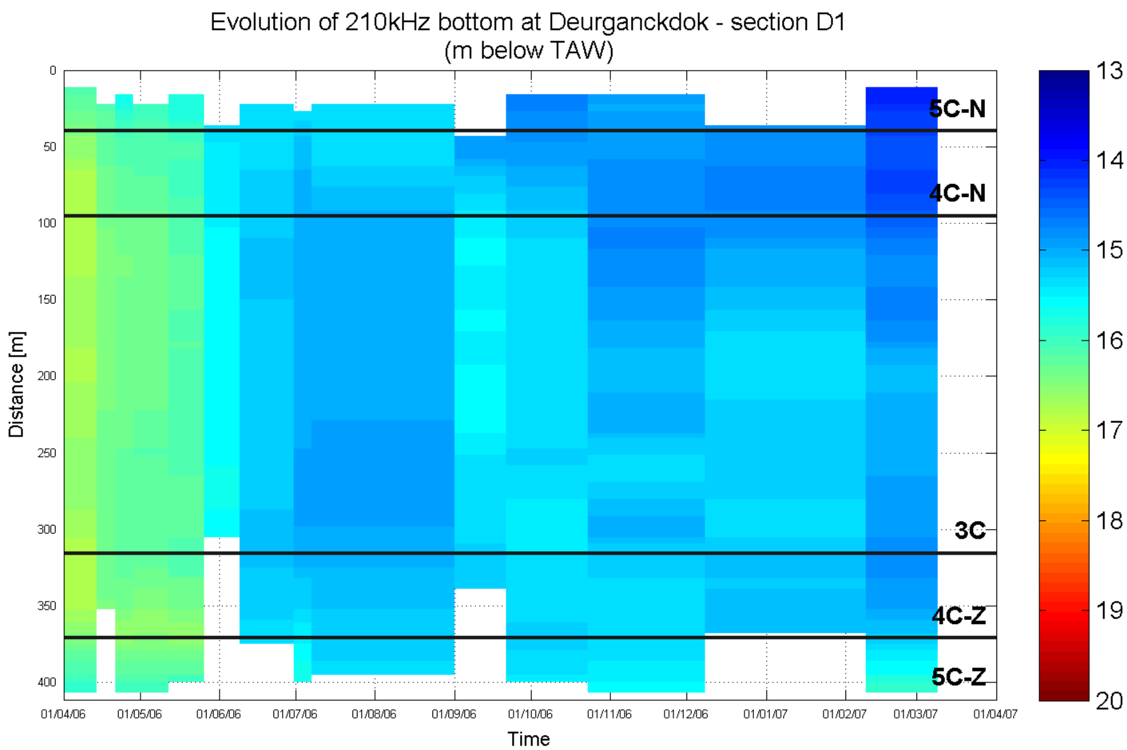
APPENDIX B. EVOLUTION OF DEPTH OF WATER-BED INTERFACE (210 KC)

B.1 Difference maps

B.2 Bed elevation evolution per section

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	210kHz depth sounder
	Location: DGD



Data Processed by: IMDC

In association with :

I/RA/11283/06.117/MSA

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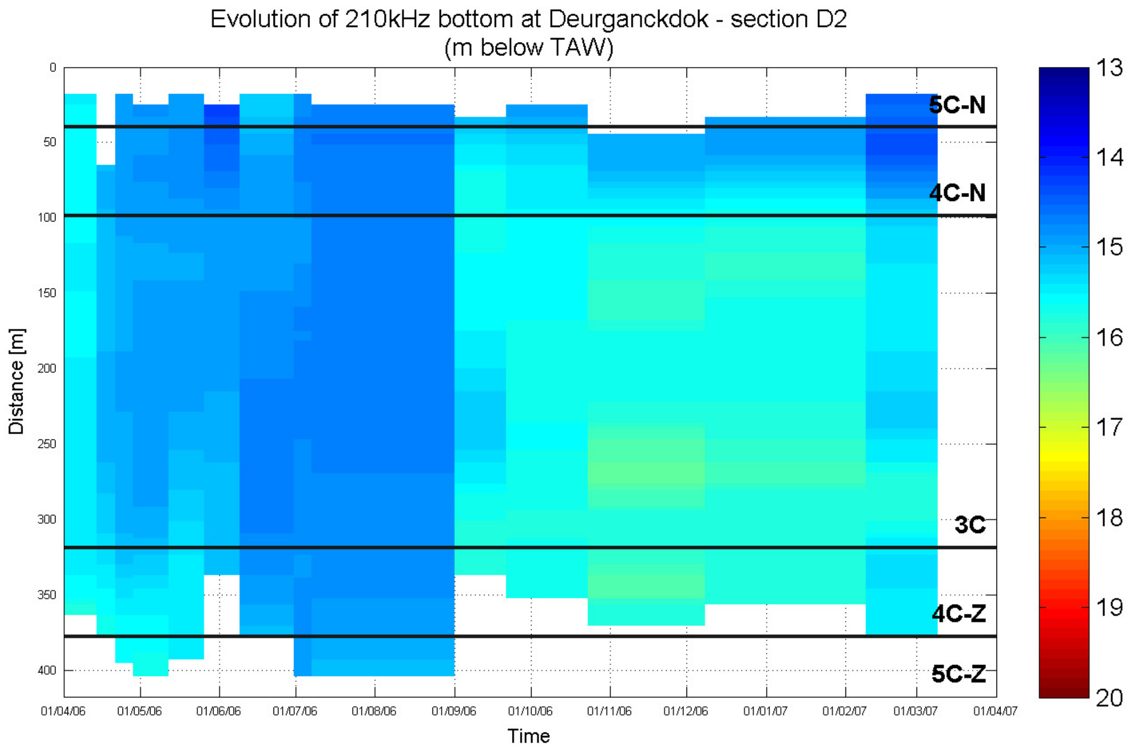
Evolution 210kHz bottom	210kHz depth sounder
	Location: DGD



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Evolution 210kHz bottom	210kHz depth sounder
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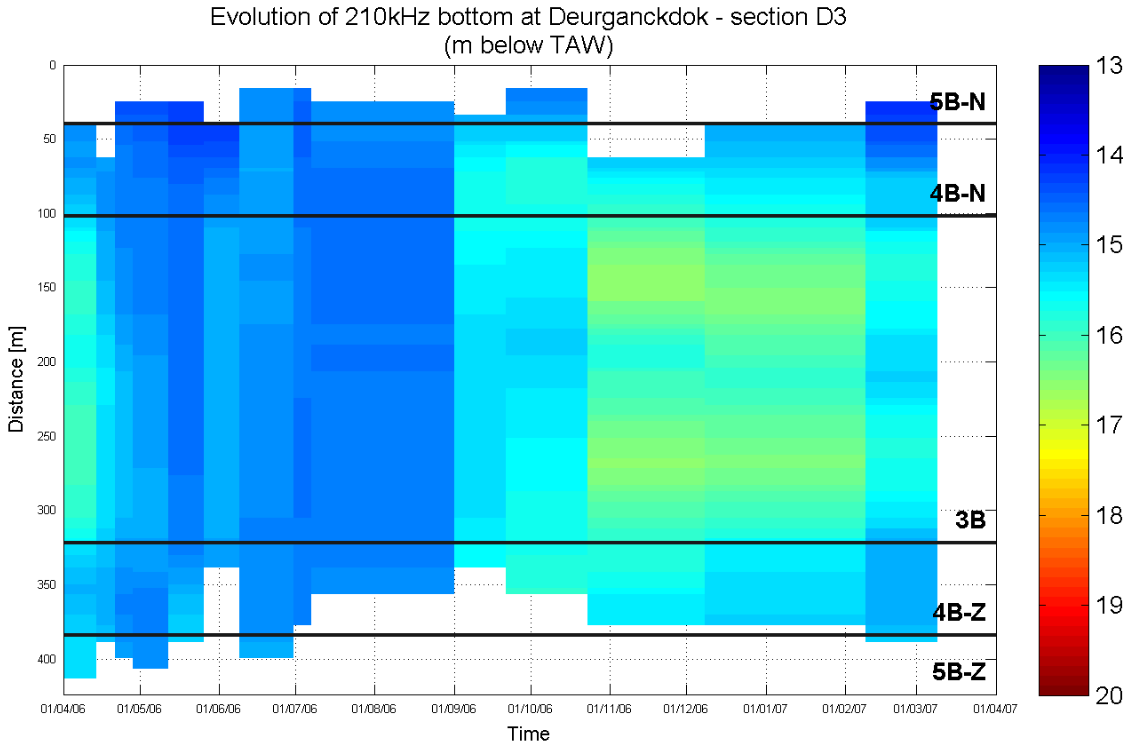

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In association with :

I/RA/11283/06.117/MSA

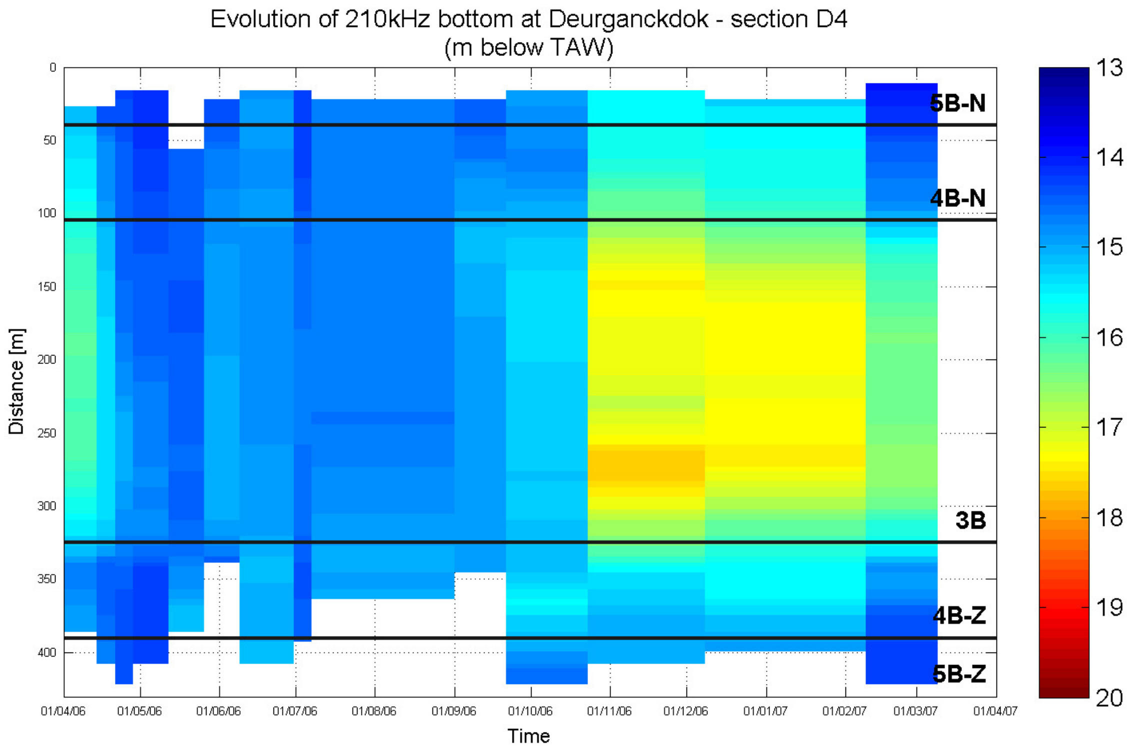
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



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I/RA/11283/06.117/MSA

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Evolution 210kHz bottom	210kHz depth sounder
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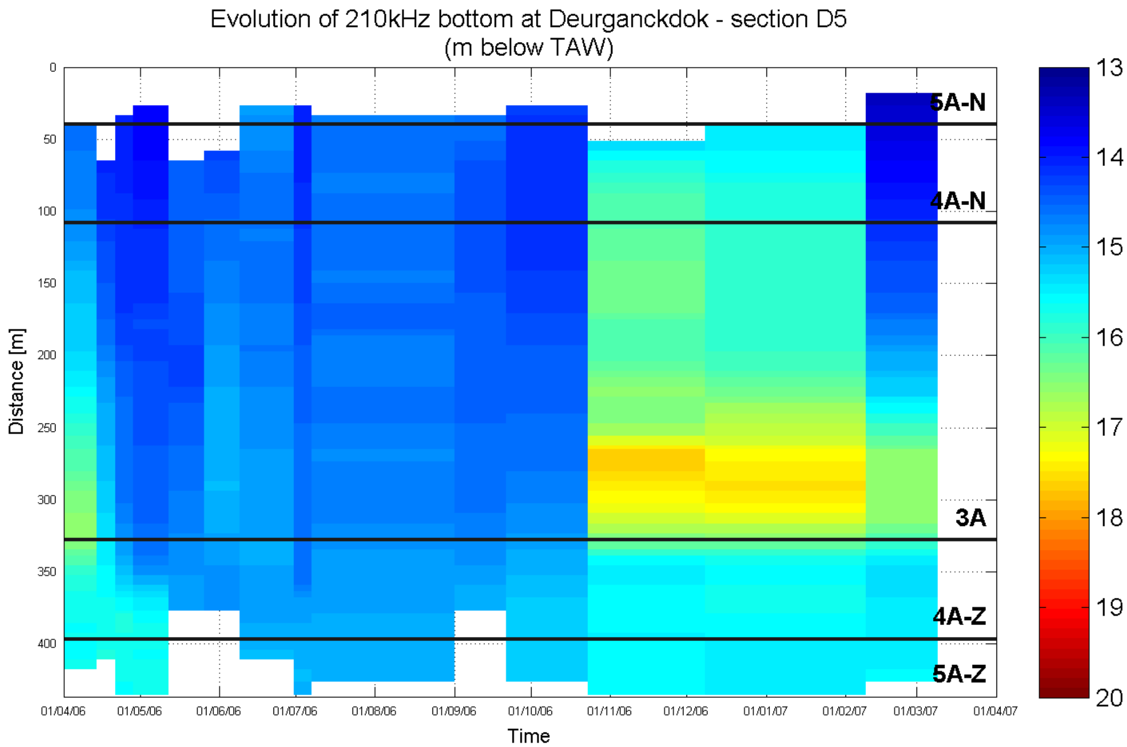

Data Processed by:

In association with :

I/RA/11283/06.117/MSA

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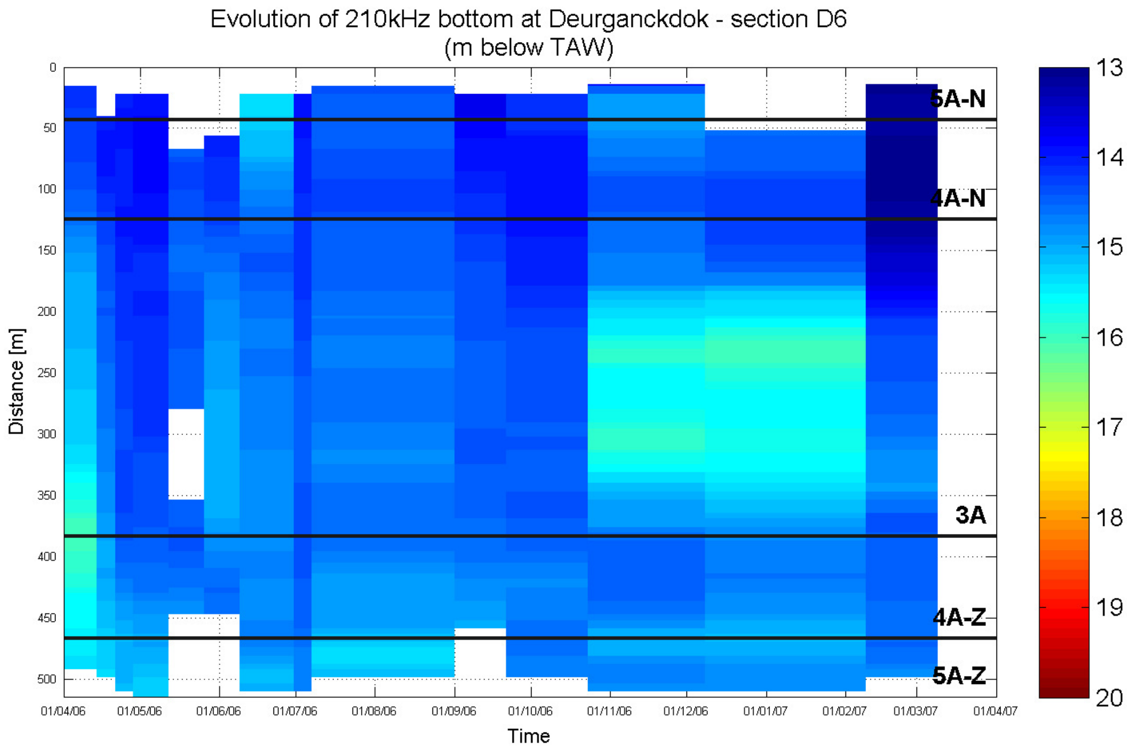
Evolution 210kHz bottom	210kHz depth sounder
	Location: DGD



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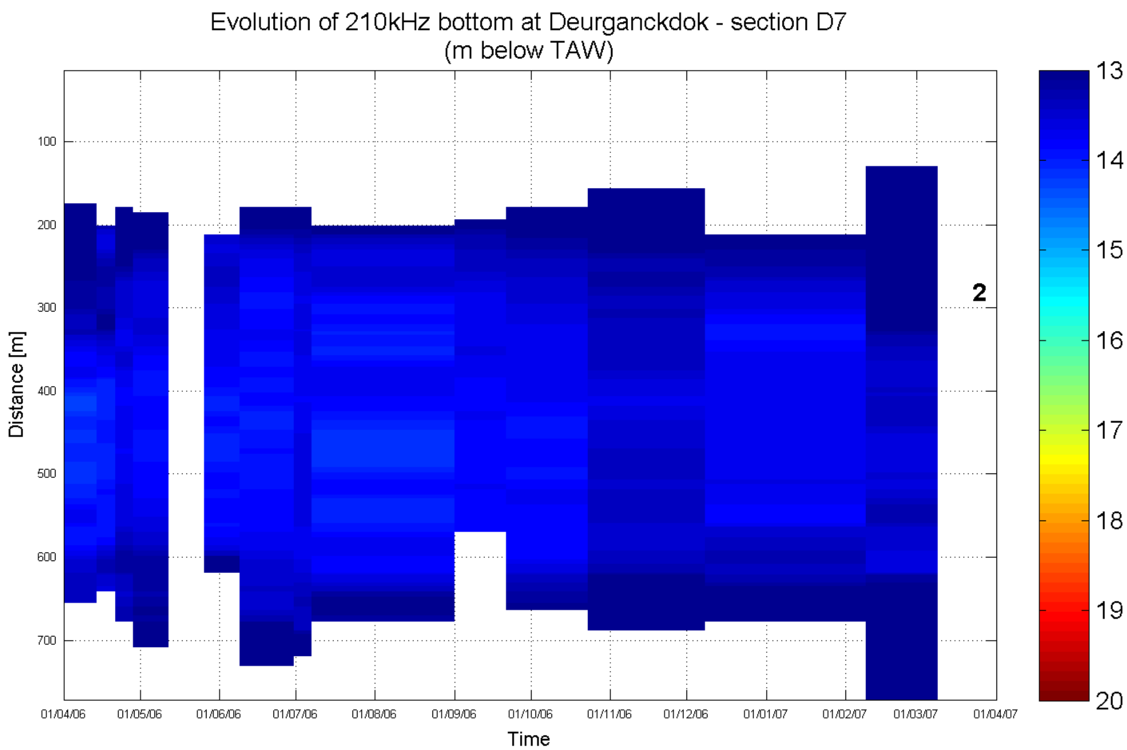
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



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I/RA/11283/06.117/MSA

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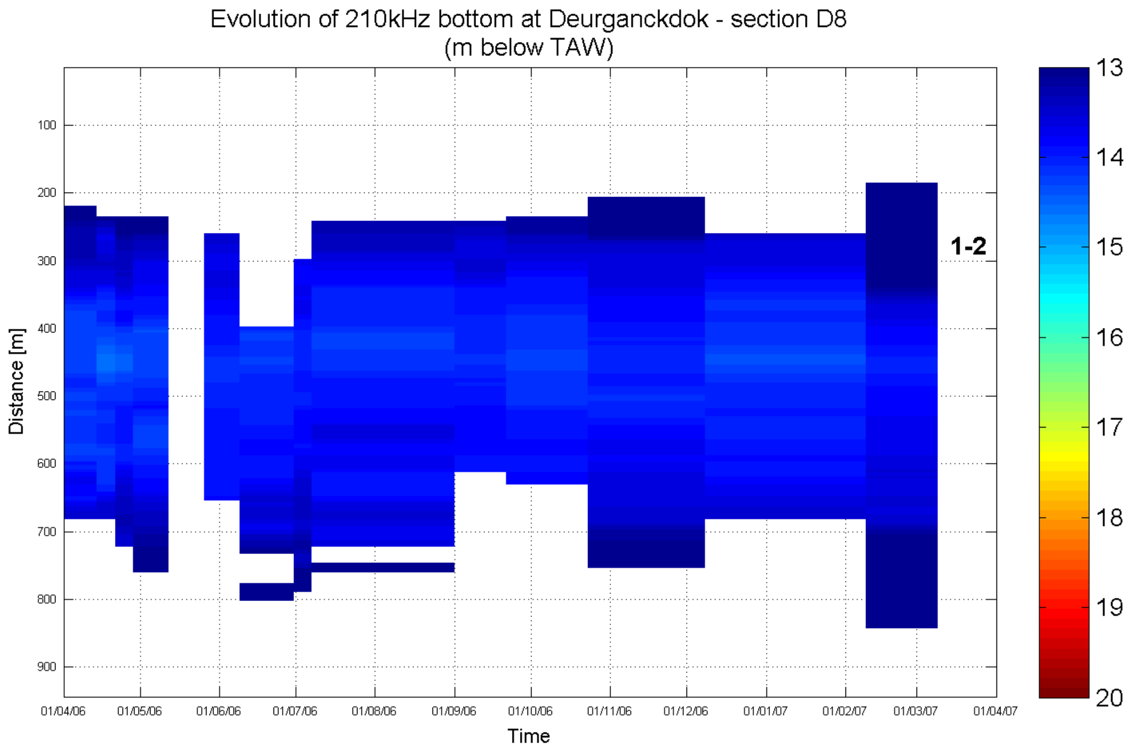
Evolution 210kHz bottom	210kHz depth sounder
	Location: DGD



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I/RA/11283/06.117/MSA

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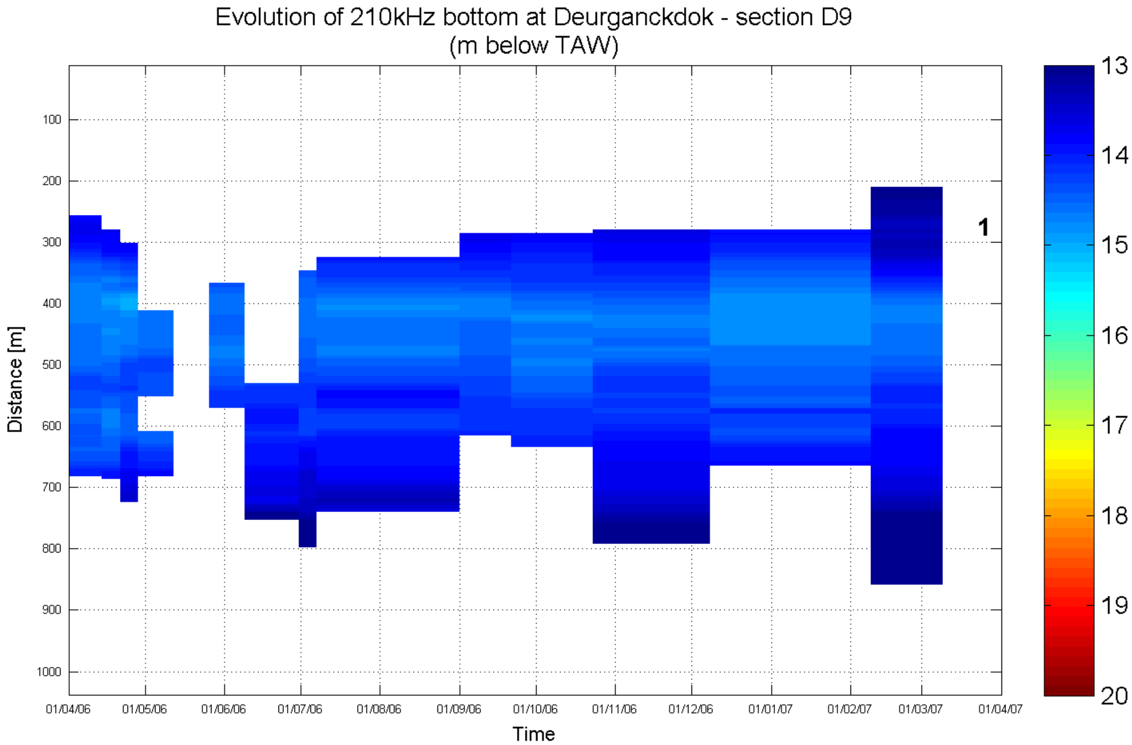

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I/RA/11283/06.117/MSA

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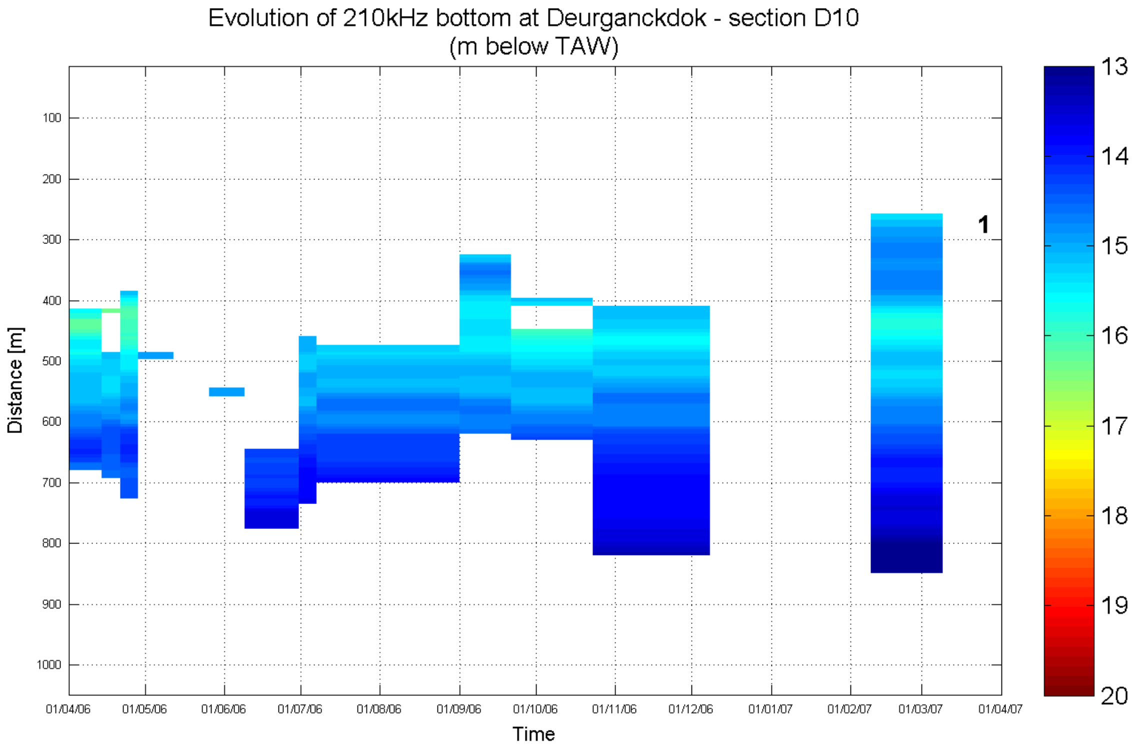
Evolution 210kHz bottom	210kHz depth sounder
	Location: DGD



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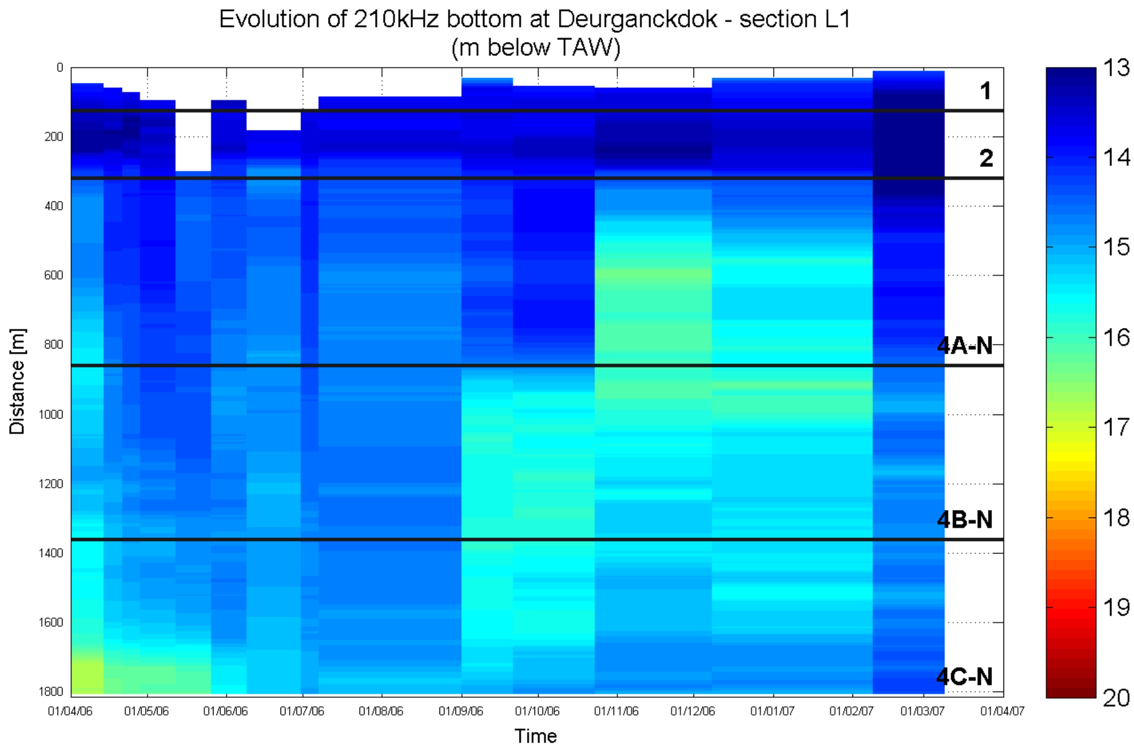
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	210kHz depth sounder
	Location: DGD



Data Processed by:

In association with :

I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok	
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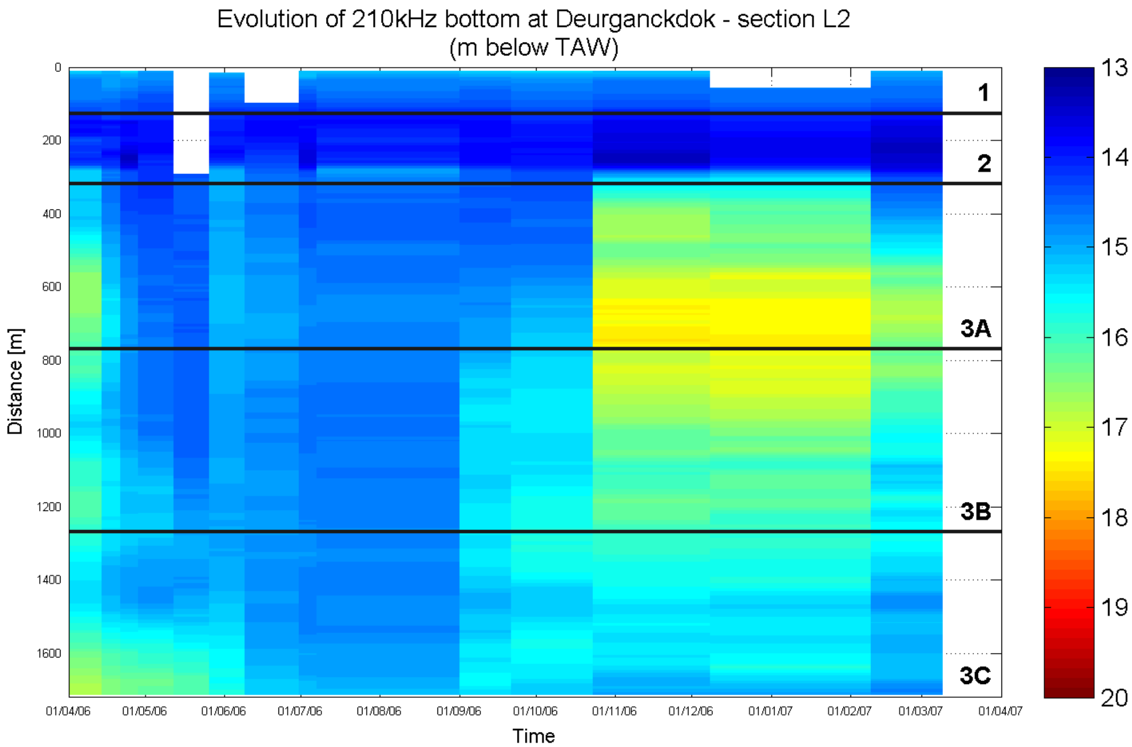
	Location: DGD



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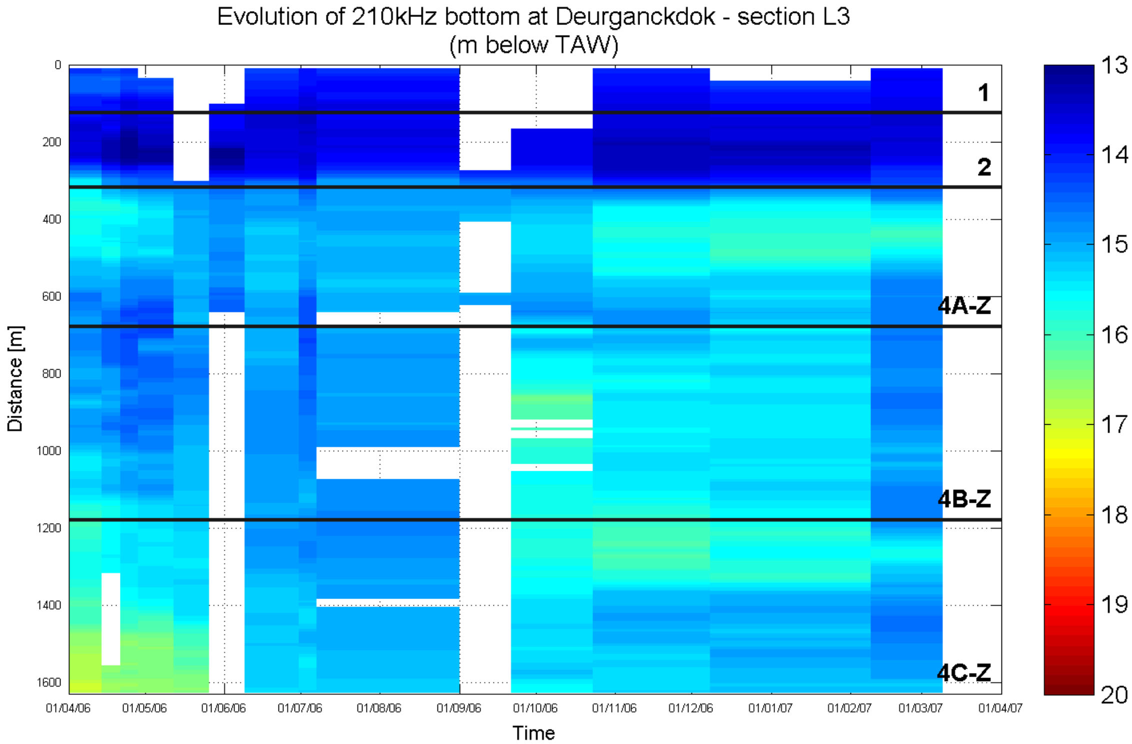
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	210kHz depth sounder
	Location: DGD



Data Processed by:

In association with :

I/RA/11283/06.117/MSA

APPENDIX C.

VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS

C.1 Siltation rates (tabular)

Siltation rates in cm/day computed from subsequent depth soundings (no monthly averaged values)

1. Per zone

	14/04/2006	21/04/2006	28/04/2006	12/05/2006	26/05/2006	09/06/2006	30/06/2006	07/07/2006	01/09/2006	21/09/2006	23/10/2006	08/12/2006	09/02/2007	09/03/2007
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0.463	3.401	0.107	-	-1.122	0.957	1.2	-4.275	0.075	0.402	1.179	-0.853	1.793	-2.138
3a	3.994	5.894	2.054	-0.085	-3.491	1.044	1.356	-1.904	0.058	-0.35	-6.377	0.386	1.452	3.247
3b	2.917	4.098	1.697	1.486	-2.527	1.014	0.909	-0.521	-1.335	-0.654	-2.91	0.026	1.113	4.088
3c	1.577	1.554	1.182	0.086	1.052	2.126	0.558	0.441	-1.138	-0.408	-0.121	0.03	0.614	3.264
4Na	3.247	1.423	2.042	-2.537	-0.379	-1.629	2.471	-6.067	0.512	1.231	-5.055	0.889	2.154	-3.026
4Nb	2.15	2.638	1.775	0.336	-1.691	-1.145	1.637	-1.464	-1.621	0.083	-0.509	0.239	1.344	0.987
4Nc	1.849	2.415	0.695	0.538	2.227	-0.95	0.987	0.862	-1.159	0.459	0.919	-0.176	0.855	0.66
4Za	0.633	3.29	1.487	-0.124	1.011	-2.451	1.808	-4.256	-	-0.054	-1.15	-0.224	0.622	0.532
4Zb	0.708	3.088	0.127	-1.234	-	0.187	1.015	-2.074	-	-1.062	0.322	0.207	0.93	-0.564
4Zc	1.476	0.604	-0.144	0.954	-	2.076	0.113	1.588	-	-0.692	0.171	0.237	0.486	1.506
5Na	-	-	2.514	-	-	-2.209	3.759	-8.057	0.718	1.434	-3.881	-	1.681	-6.312
5Nb	-	-	1.46	0.125	-	-1.892	1.661	-3.179	-0.299	0.567	-	-	0.533	-0.691
5Nc	-	-	0.15	0.154	-	0.057	0.978	1.968	-0.116	0.337	-0.292	-	0.726	-2.874
5Za	-	-	2.557	-	-	-	-	-	-	-0.122	-1.029	0.189	0.747	-
5Zb	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5Zc	-	-	-	1.275	-	-	0.902	-	-	0.213	-	-	0.063	-

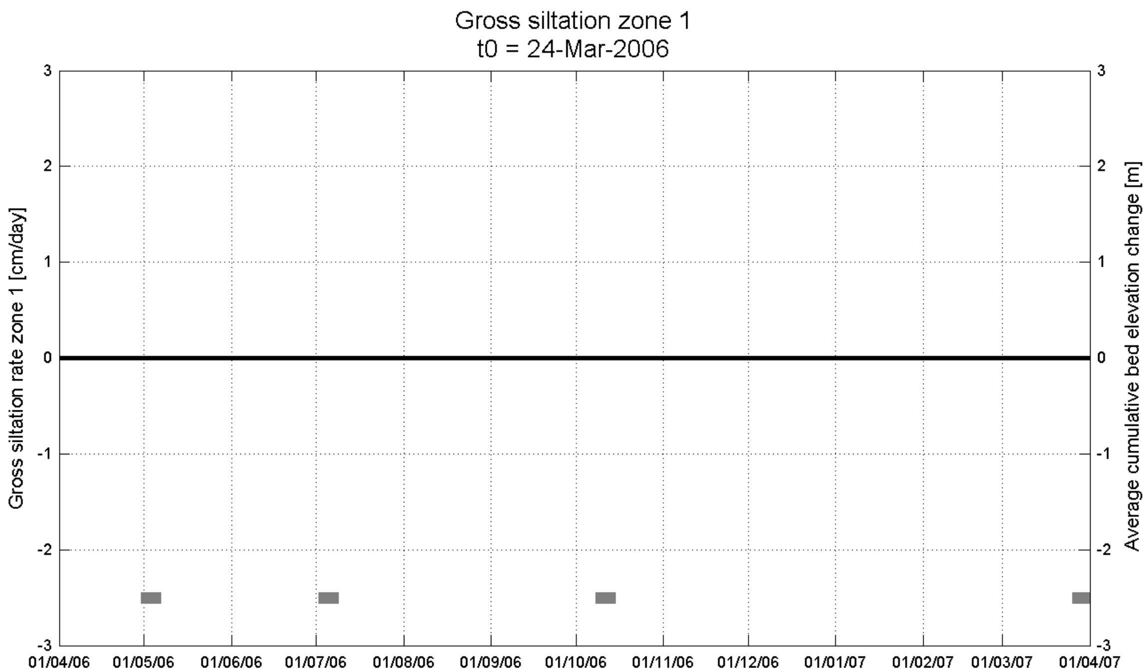
2. Per section

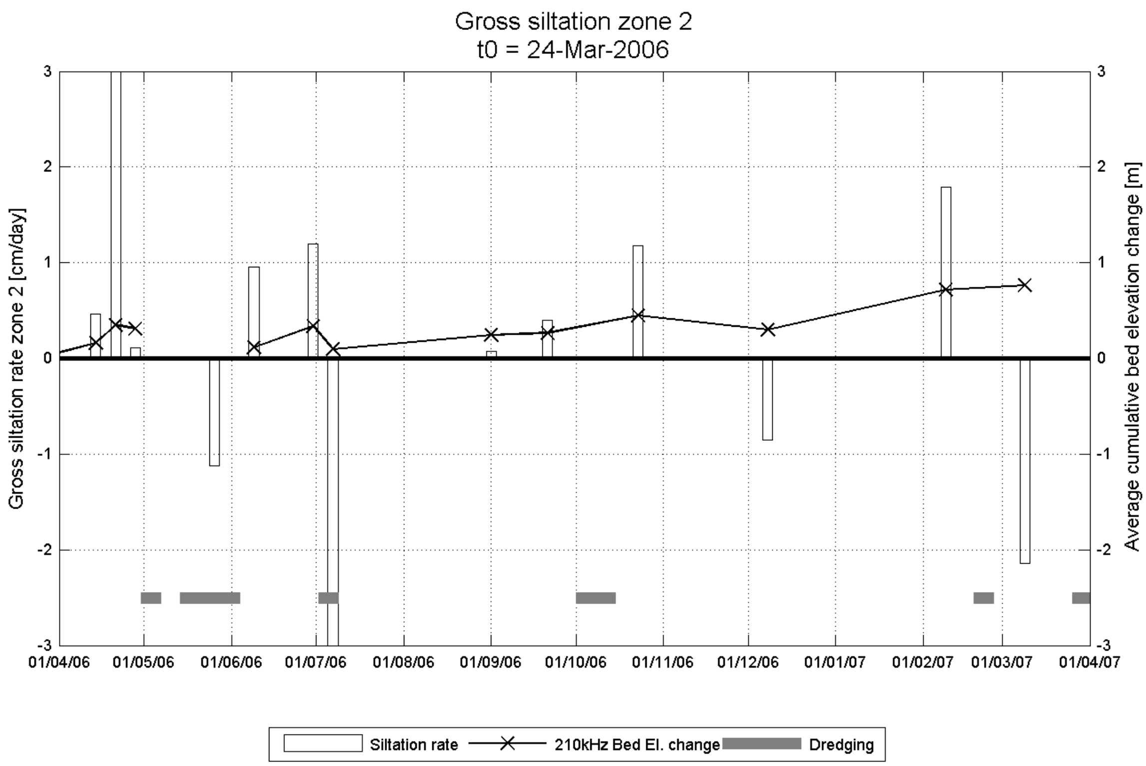
	14/04/2006	21/04/2006	28/04/2006	12/05/2006	26/05/2006	09/06/2006	30/06/2006	07/07/2006	01/09/2006	21/09/2006	23/10/2006	08/12/2006	09/02/2007	09/03/2007
D1	1.09	1.58	-0.23	0.83	4.16	2.28	0.57	0.35	-0.48	0.63	0.47	-0.04	0.47	1.28
D2	1.54	1.72	0.28	-0.15	1.22	0.28	0.33	0.57	-1.36	-0.19	-0.56	0.21	0.60	2.99
D3	1.70	4.24	1.32	0.90	-1.71	0.29	1.00	-0.43	-1.36	-0.37	-1.55	0.34	0.91	2.28
D4	2.97	6.06	2.21	-0.69	-2.17	-0.34	1.86	-3.37	-0.28	-1.03	-4.31	0.19	1.56	2.48
D5	2.64	3.97	1.92	-0.10	-1.80	-0.01	1.48	-3.29	0.27	-0.12	-4.97	0.25	1.62	0.35
D6	2.39	3.52	0.55	-1.08	-1.42	-0.81	2.15	-4.52	0.50	0.21	-1.95	-0.09	1.56	-2.17
D7	-0.45	2.93	-0.41	-	-0.78	1.16	0.29	-3.79	-	0.22	1.84	-1.18	2.11	-2.88
D8	-	-	-0.09	-	-	-	0.21	-2.16	-	-	0.23	NaN	0.78	-1.96
D9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L1	2.06	1.49	1.04	-1.57	0.78	-1.50	1.83	-2.32	-0.60	0.52	-1.21	0.24	1.46	-0.56
L2	2.29	3.67	1.51	-0.10	-1.22	1.43	0.82	-0.72	-0.54	-0.64	-2.44	-0.14	0.99	3.03
L3	1.39	0.62	-0.27	-1.67	-	1.46	0.80	-1.81	-	-0.73	0.70	-0.06	0.63	0.47

C.2 Water-bed interface evolution for all zones

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

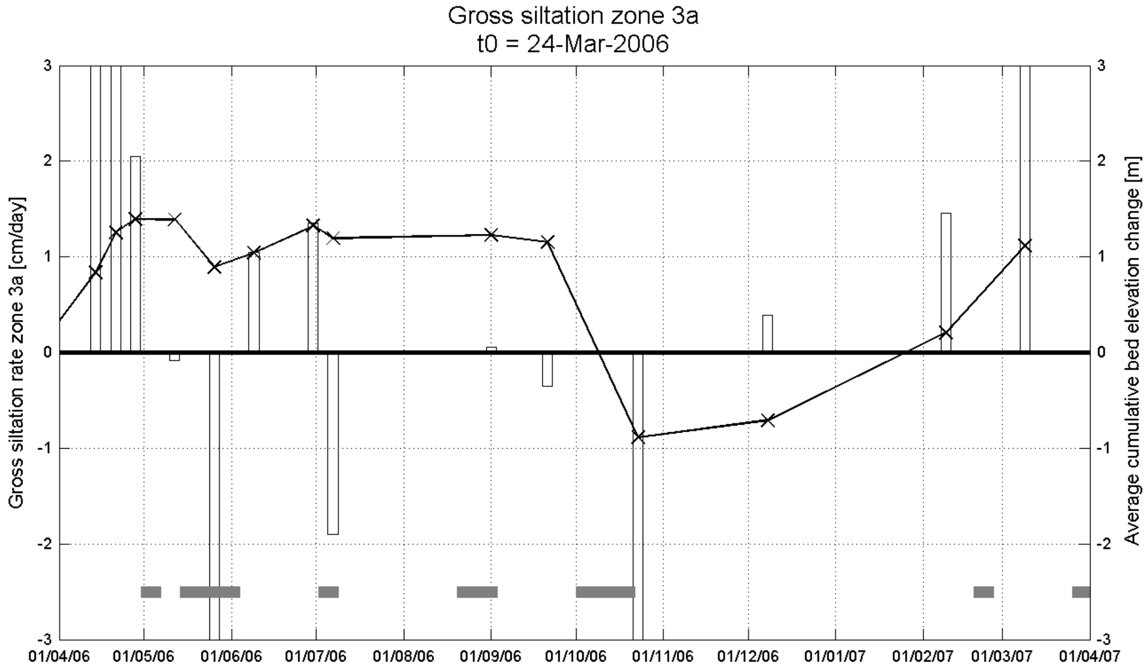
Data Processed by: IMDC

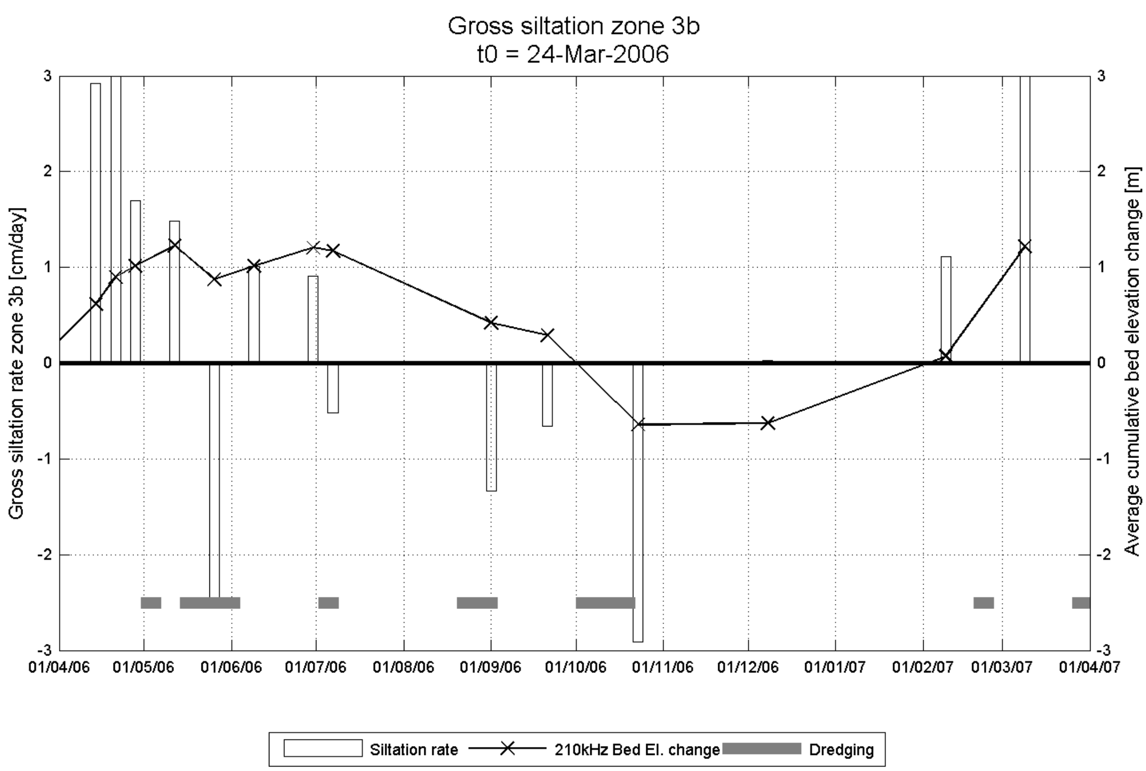
In association with :

I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
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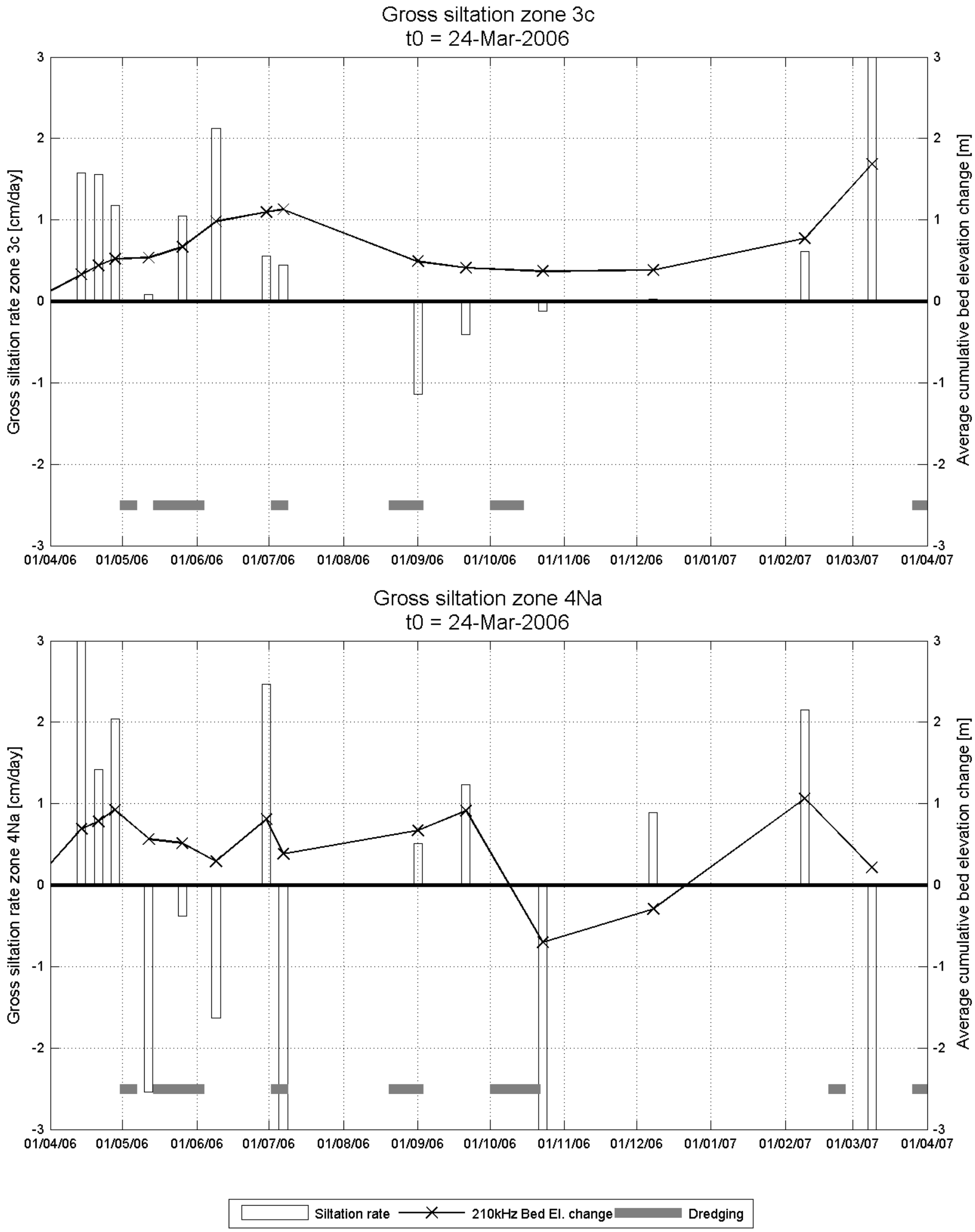

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In association with :

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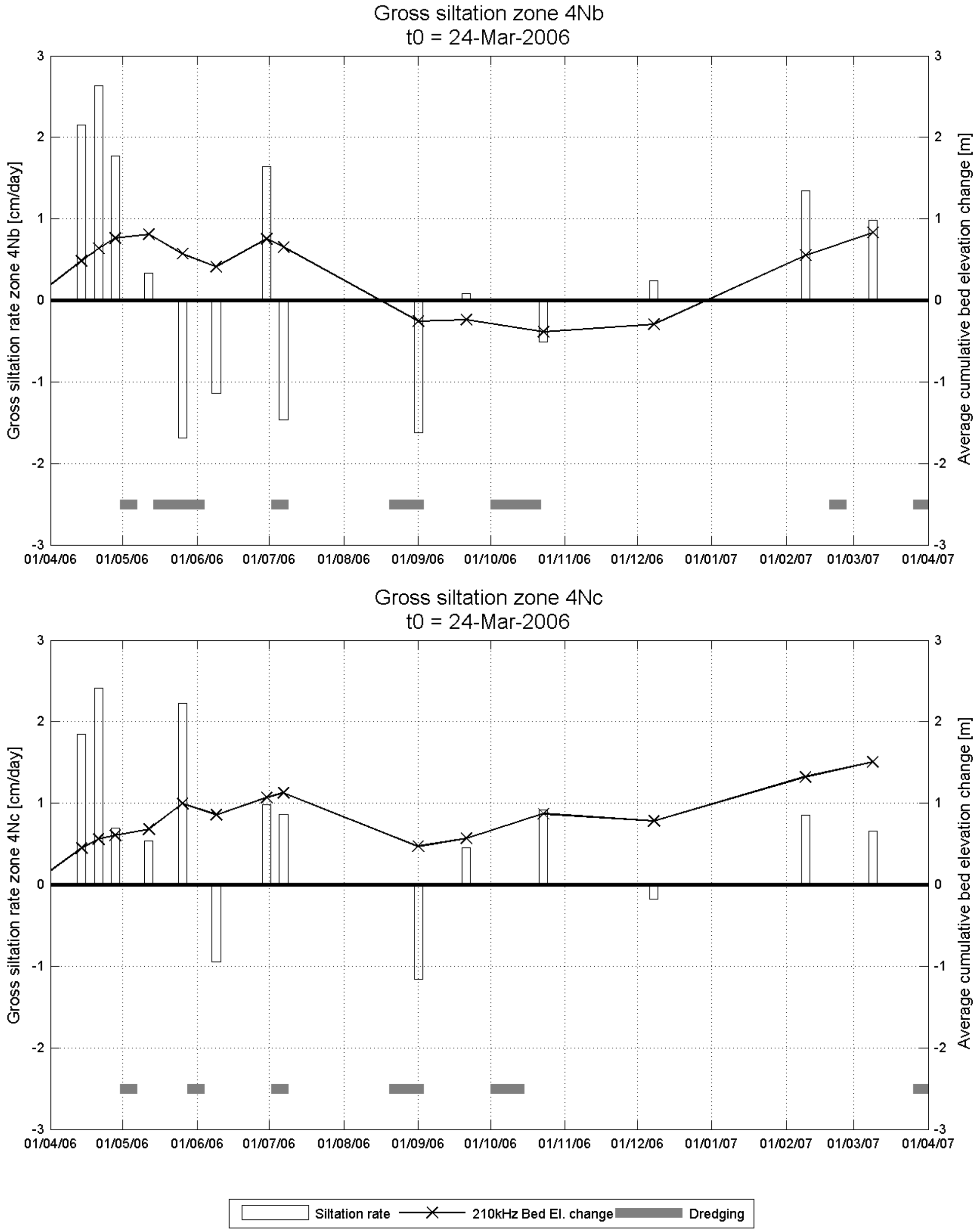
Long-term monitoring siltation Deurganckdok	
Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



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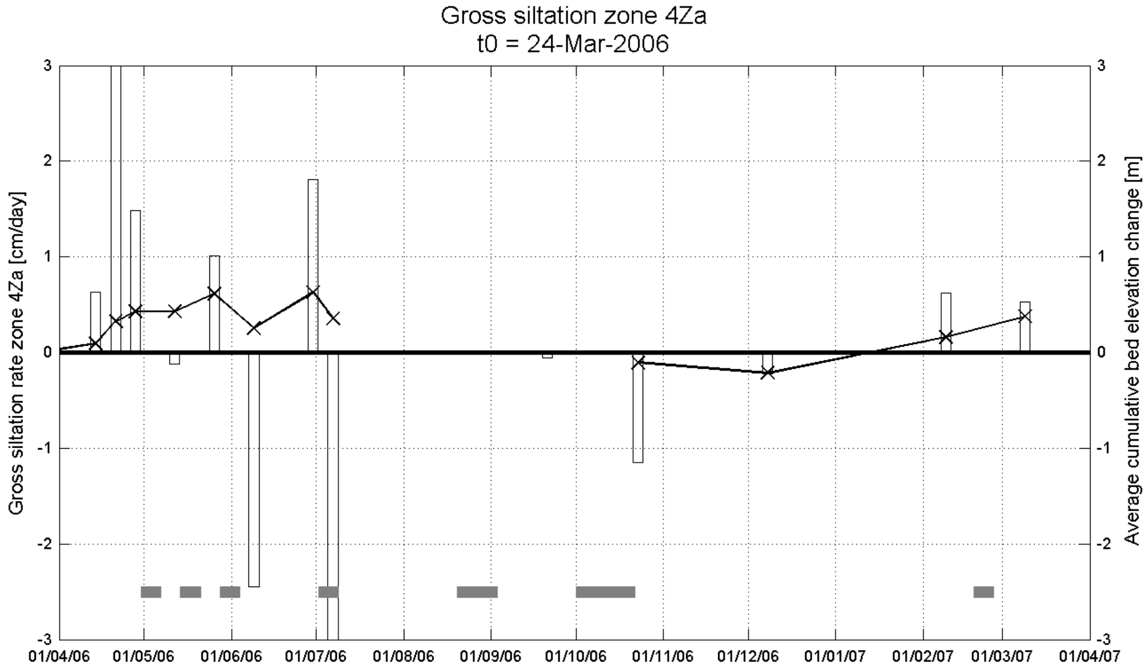
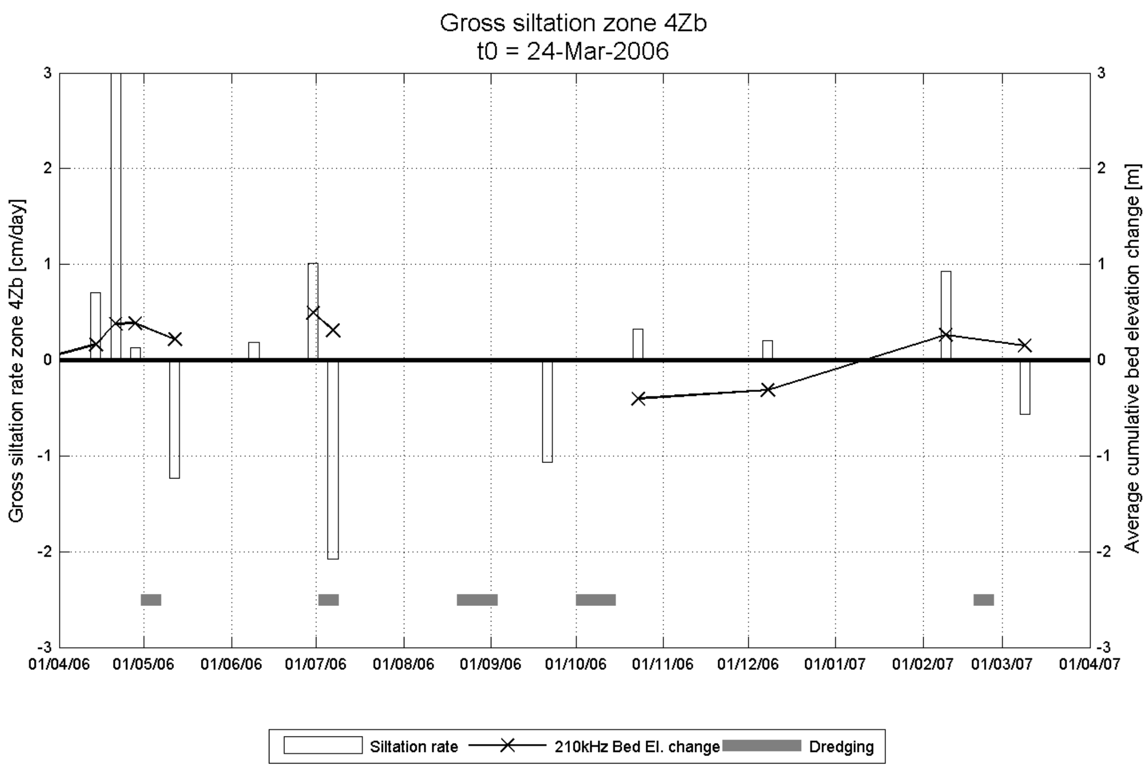
Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





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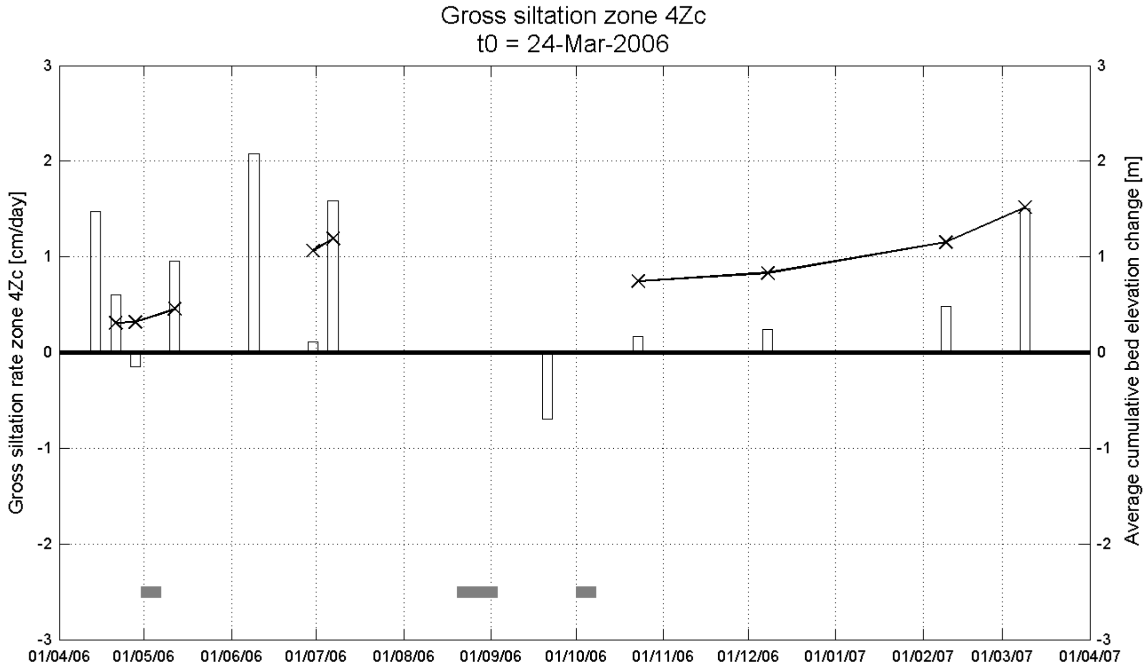
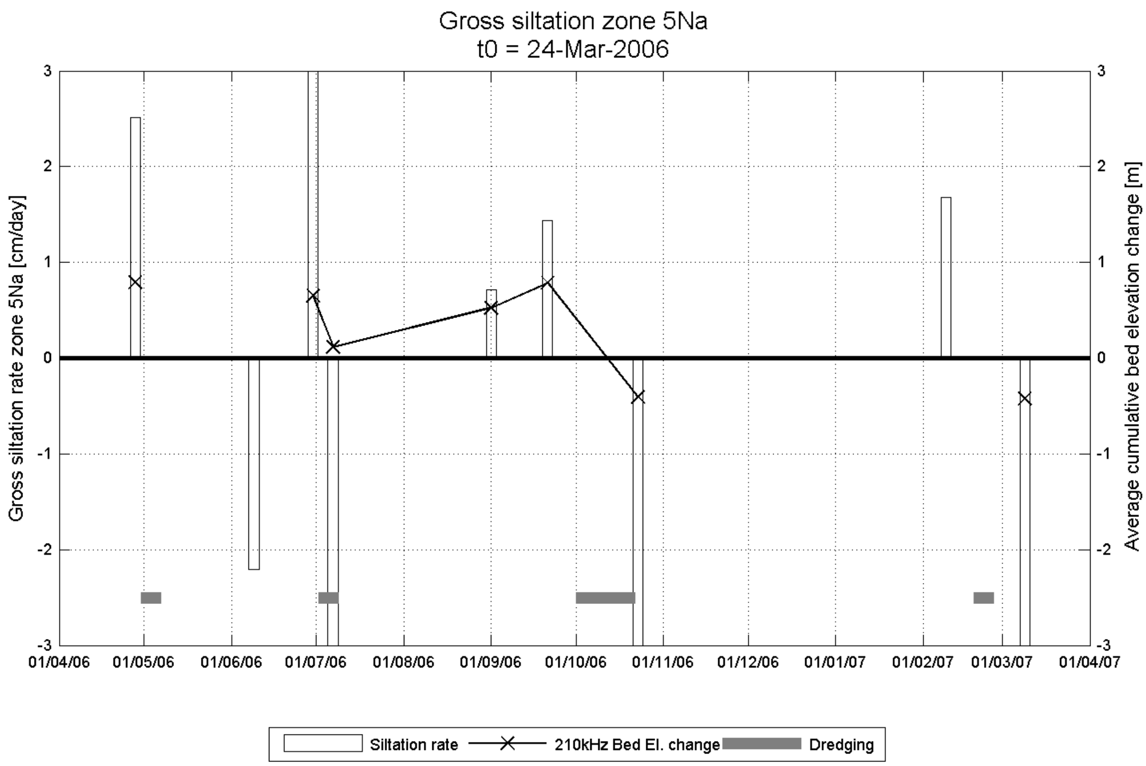
In association with :

I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





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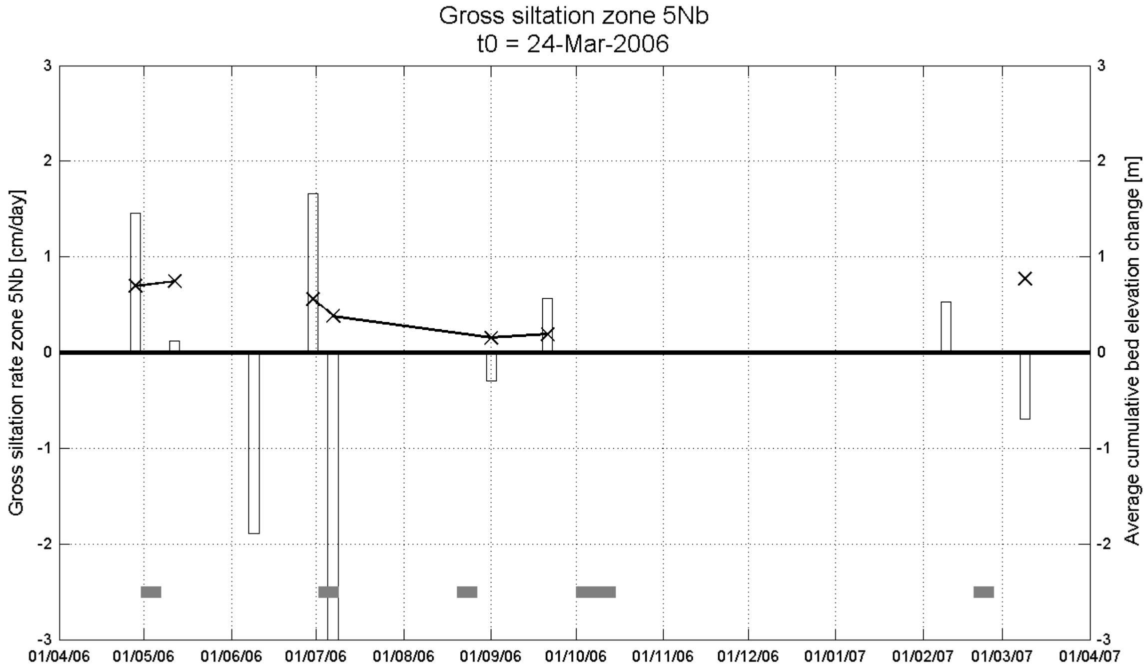
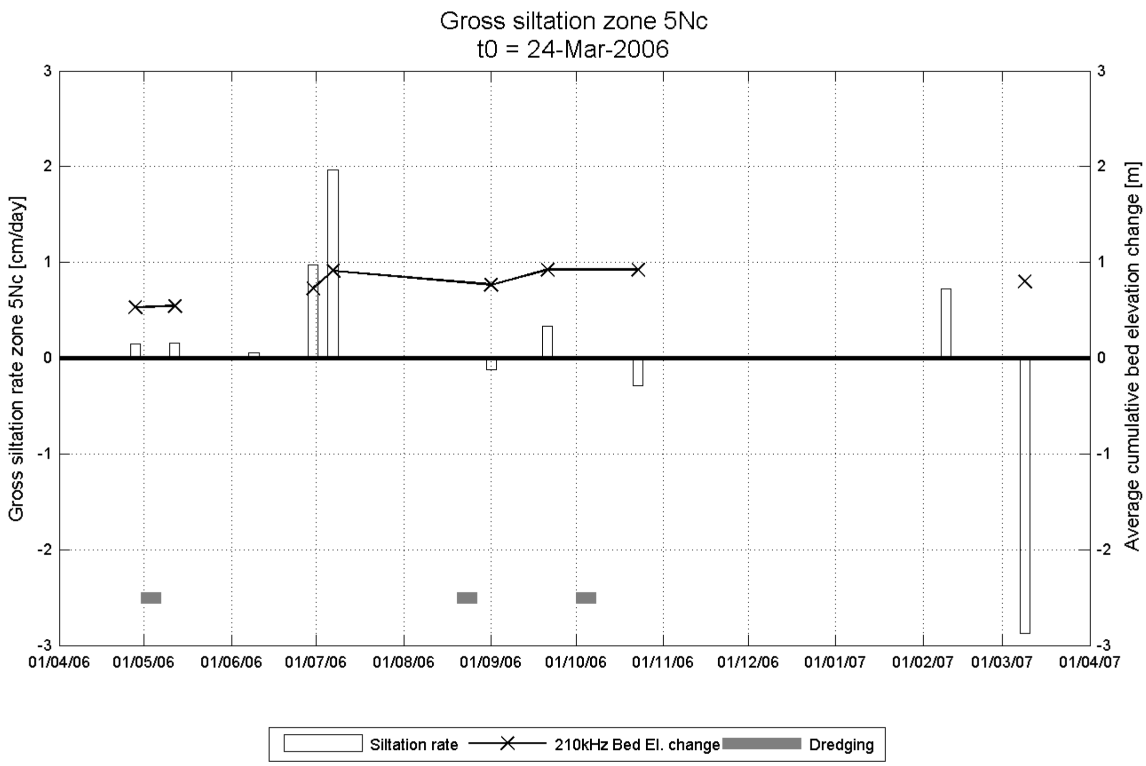
Data Processed by:

In association with :

I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok	
Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

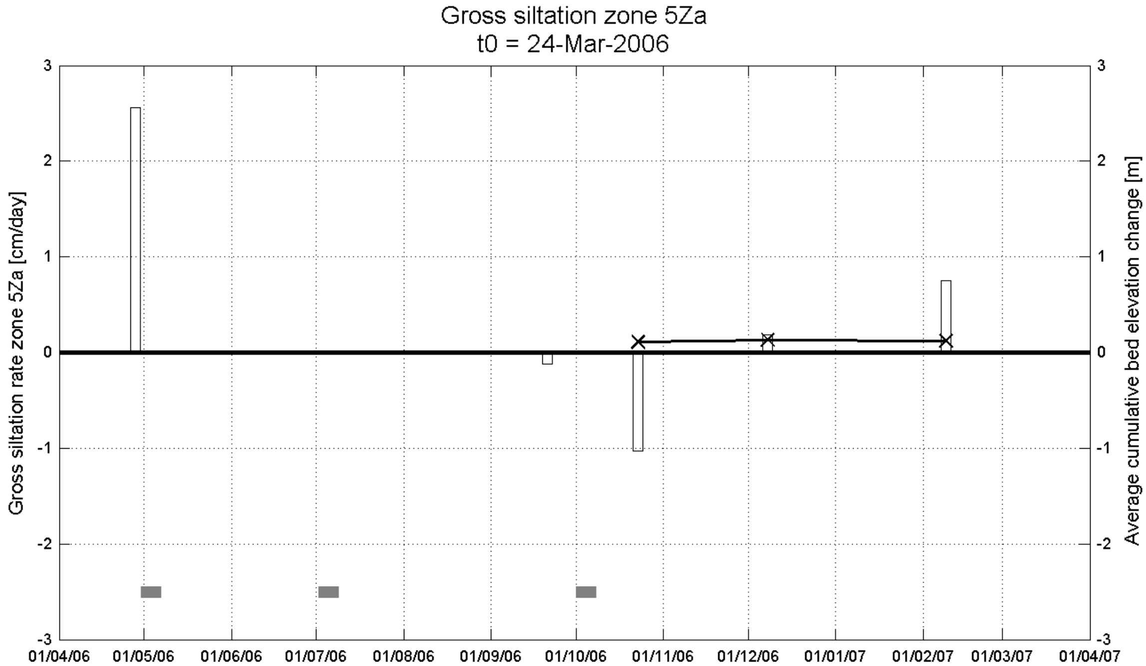


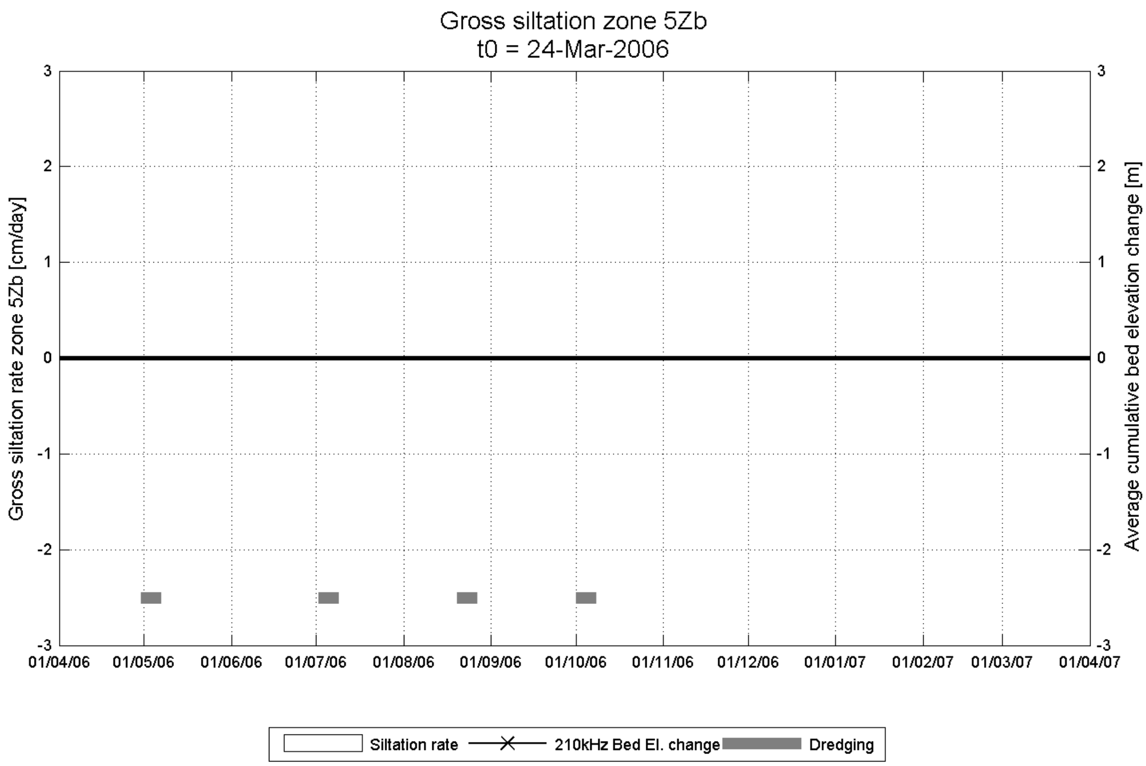


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





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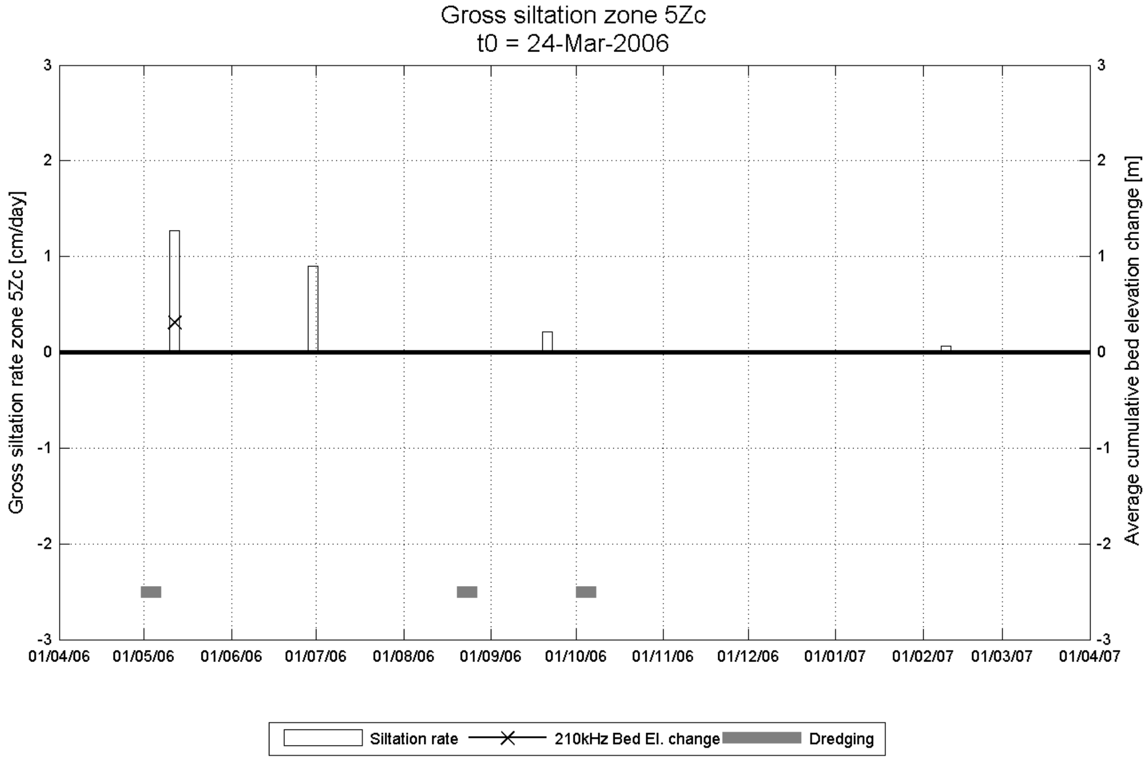
Data Processed by: IMDC

In association with :

I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 24-Mar-2006

Data Processed by:

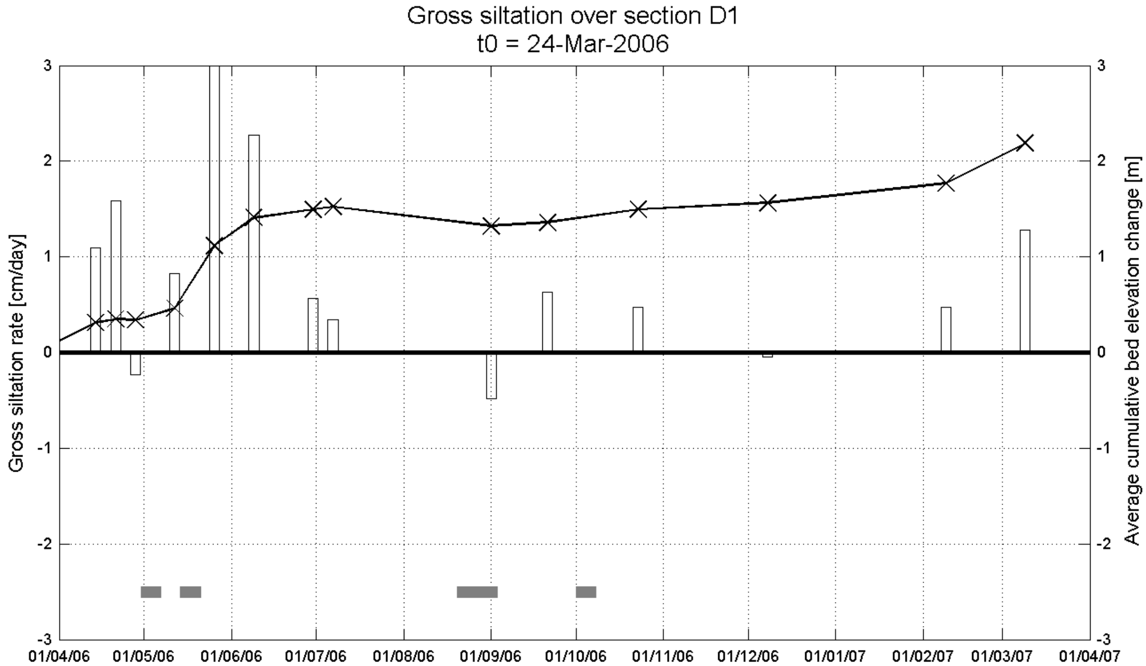
In association with :

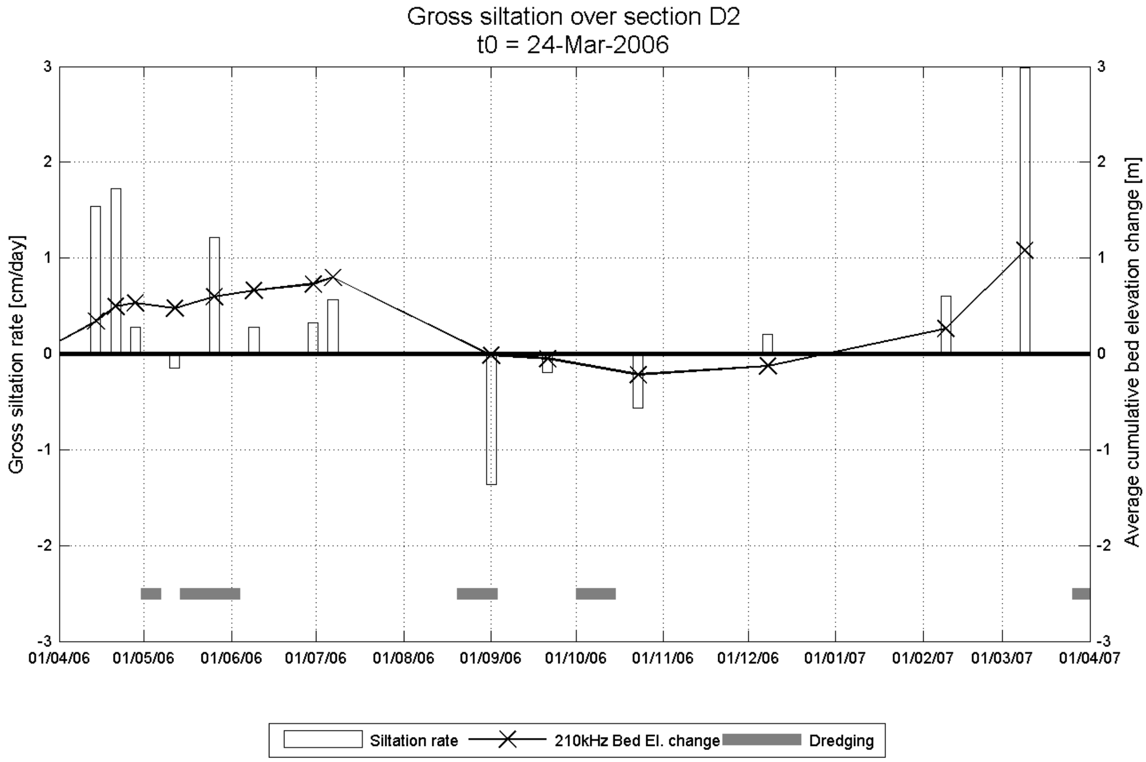
I/RA/11283/06.117/MSA

C.3 Water-bed interface evolution for all sections

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

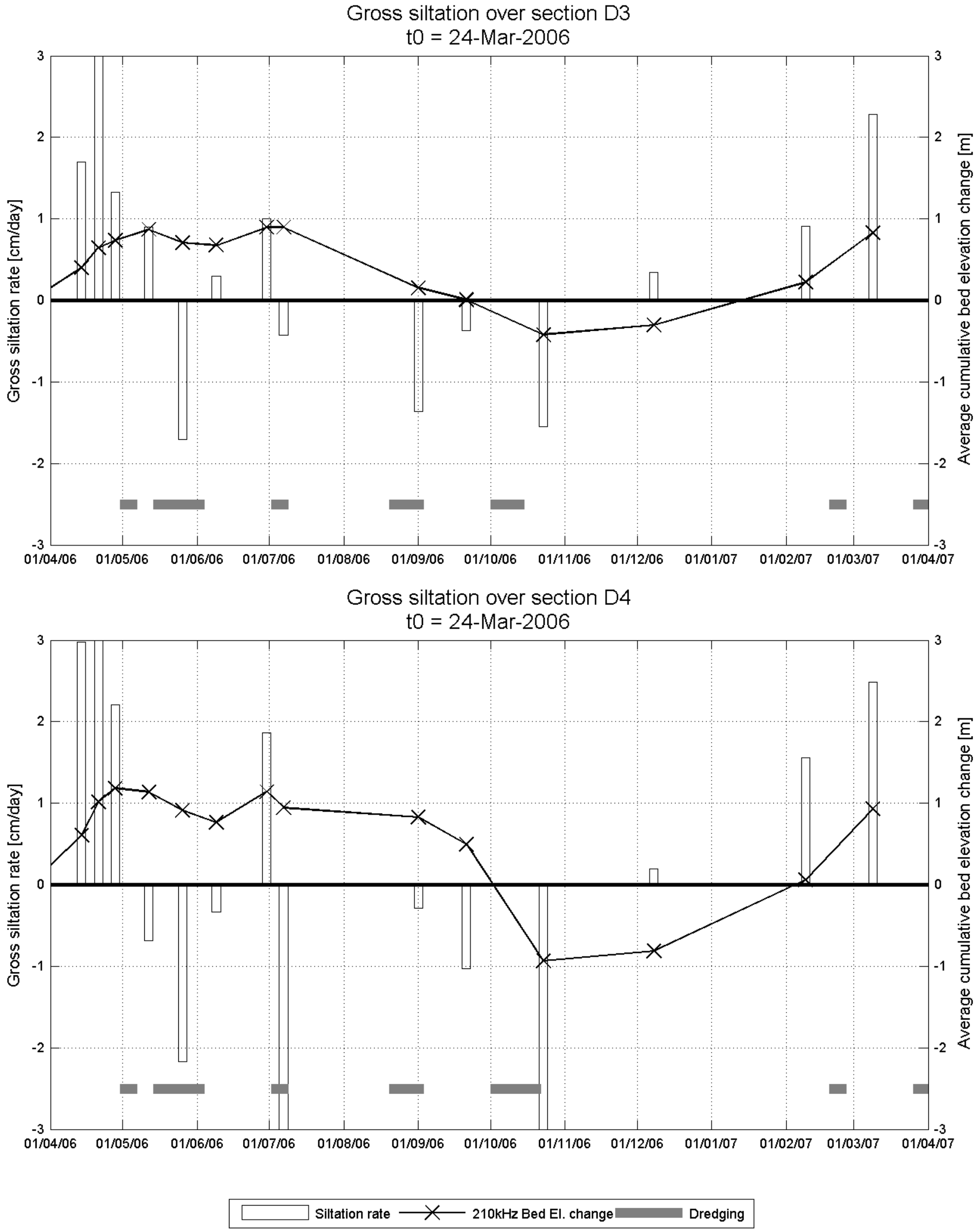
Data Processed by:

In association with :

I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 24-Mar-2006

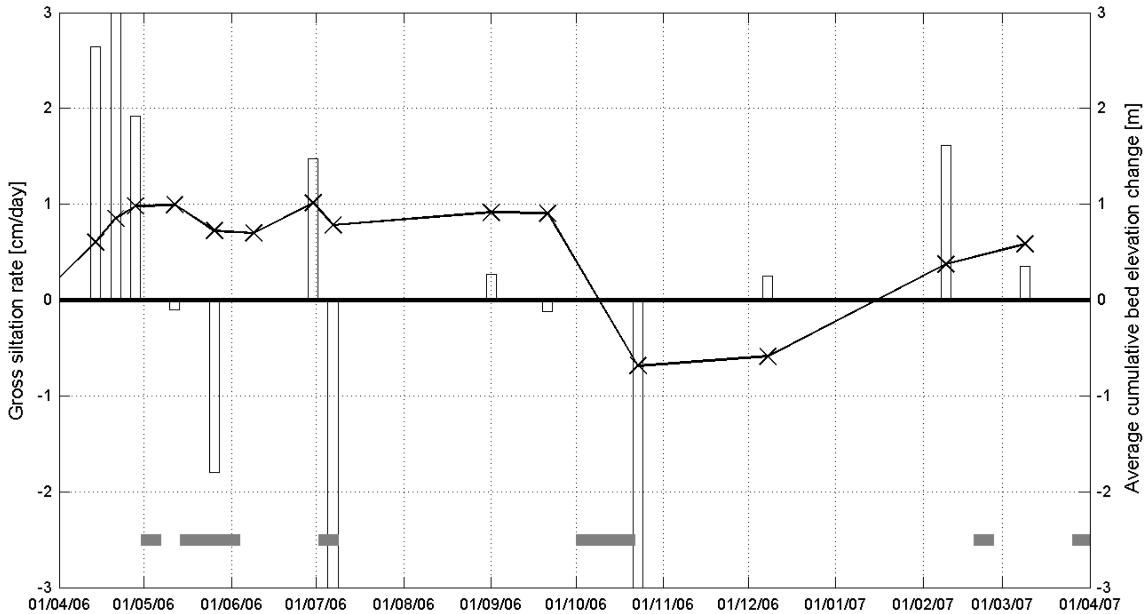
Data Processed by:
In association with :

I/RA/11283/06.117/MSA

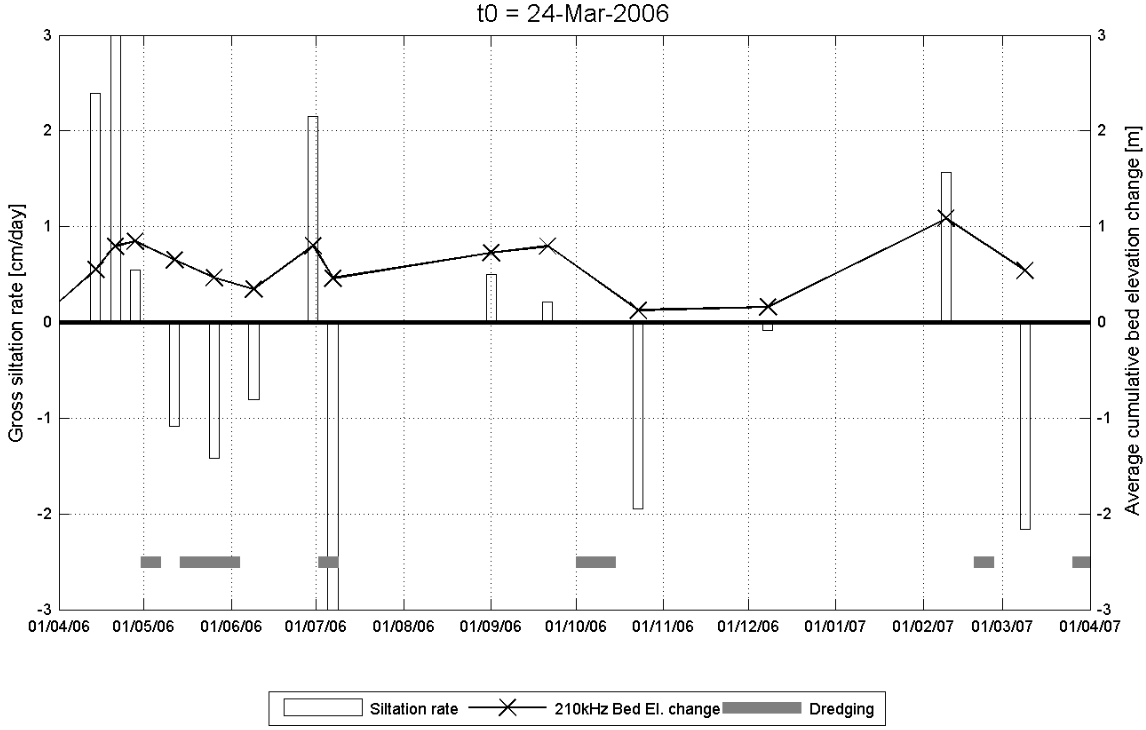
Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

Gross siltation over section D5
t0 = 24-Mar-2006



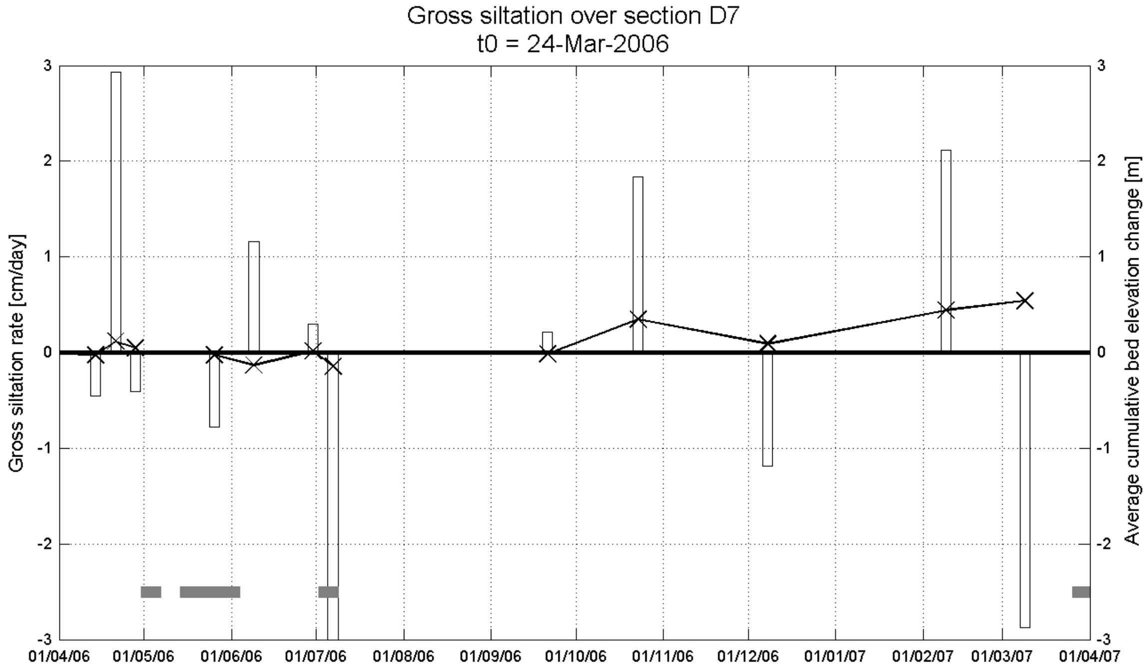
Gross siltation over section D6
t0 = 24-Mar-2006

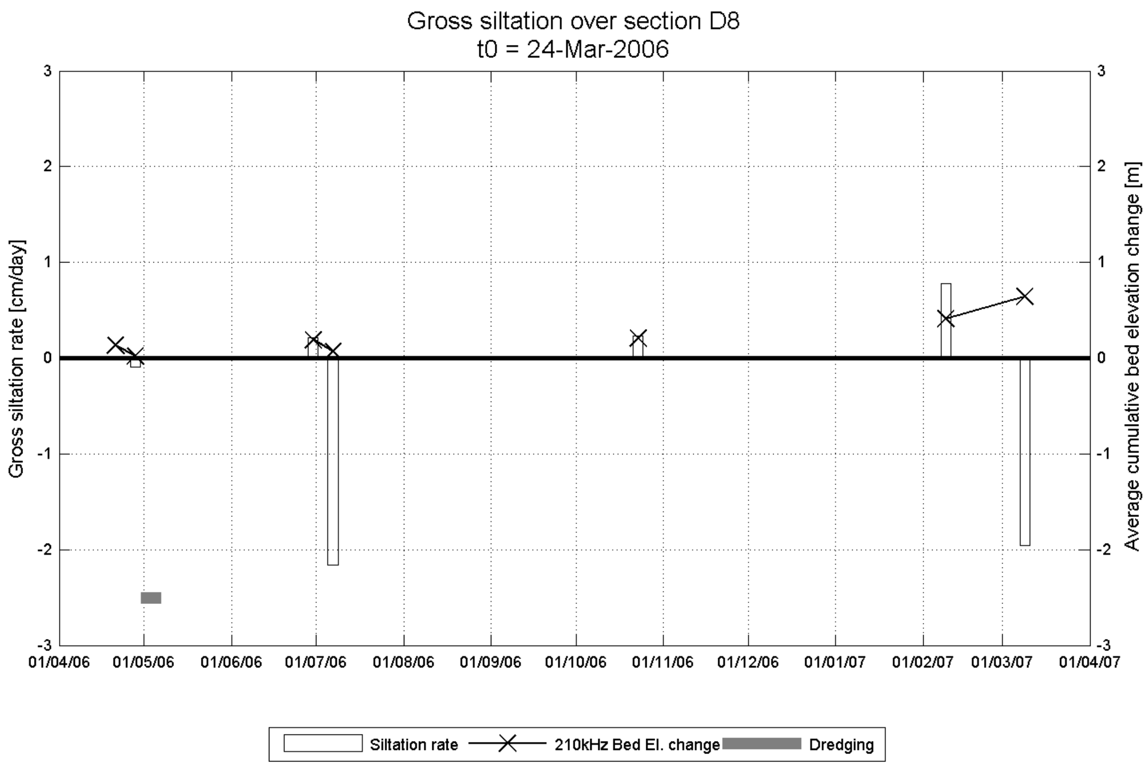


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

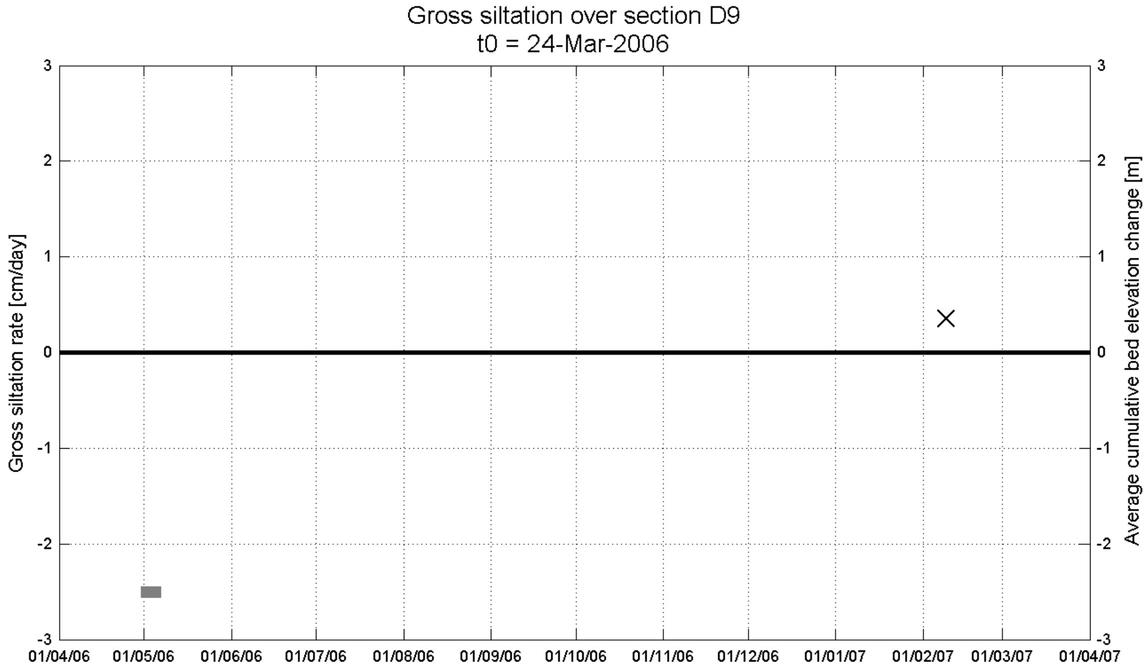
Data Processed by: IMDC

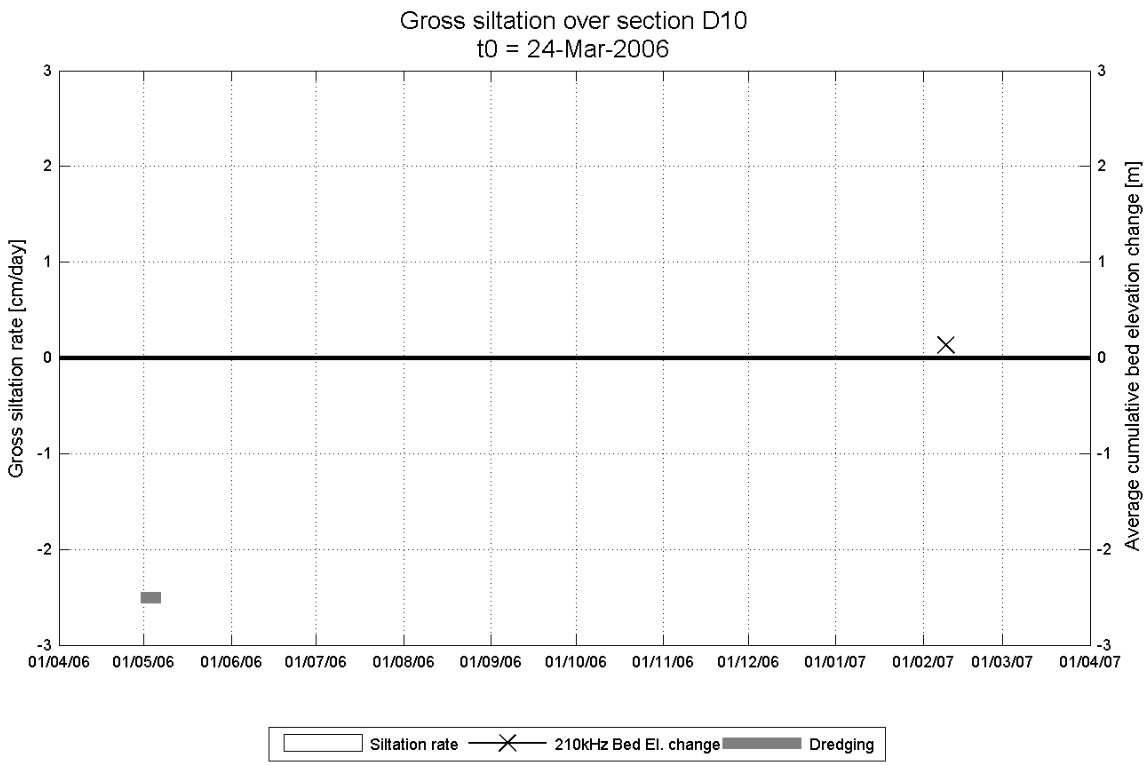
In association with :

I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

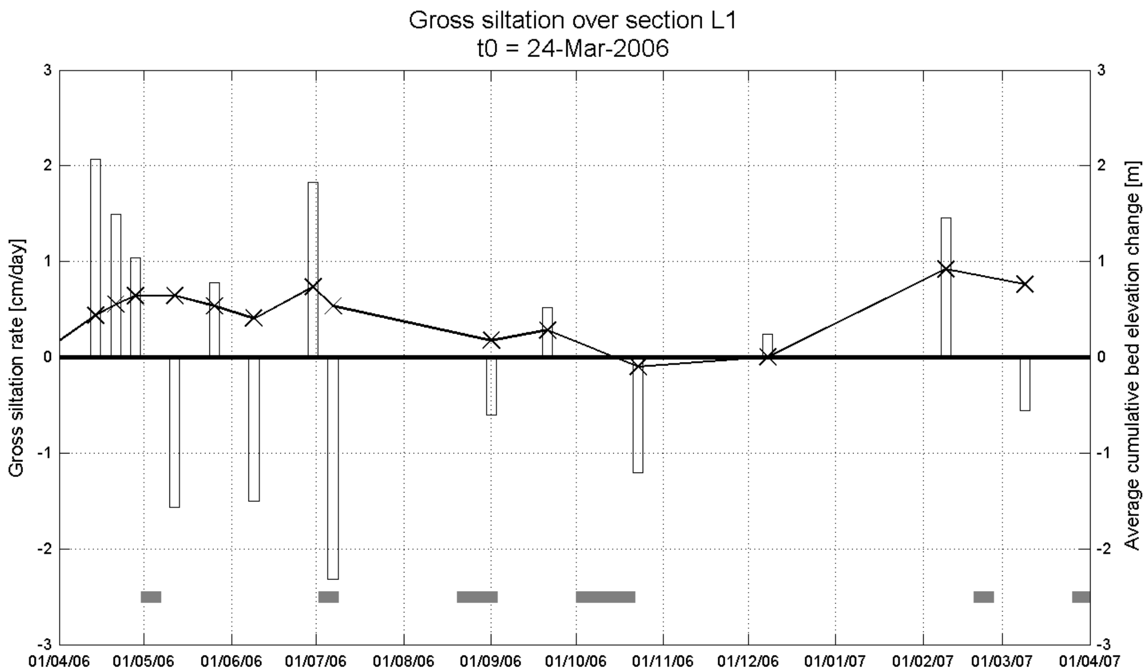


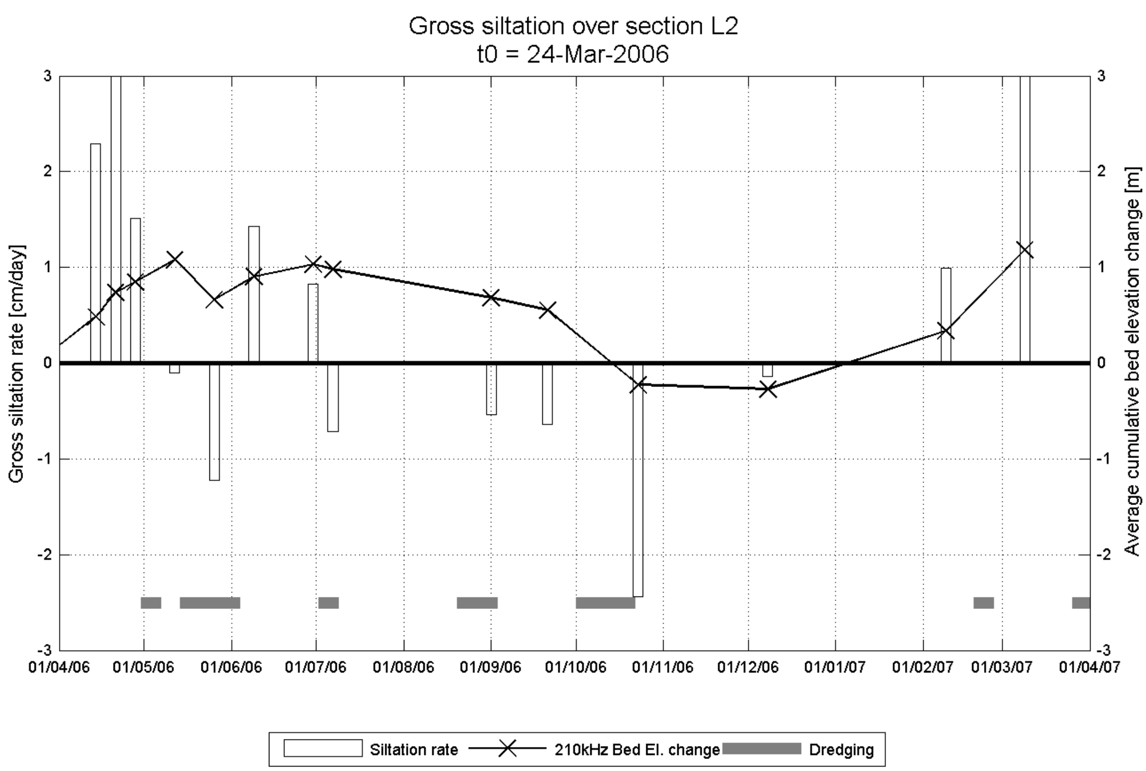


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

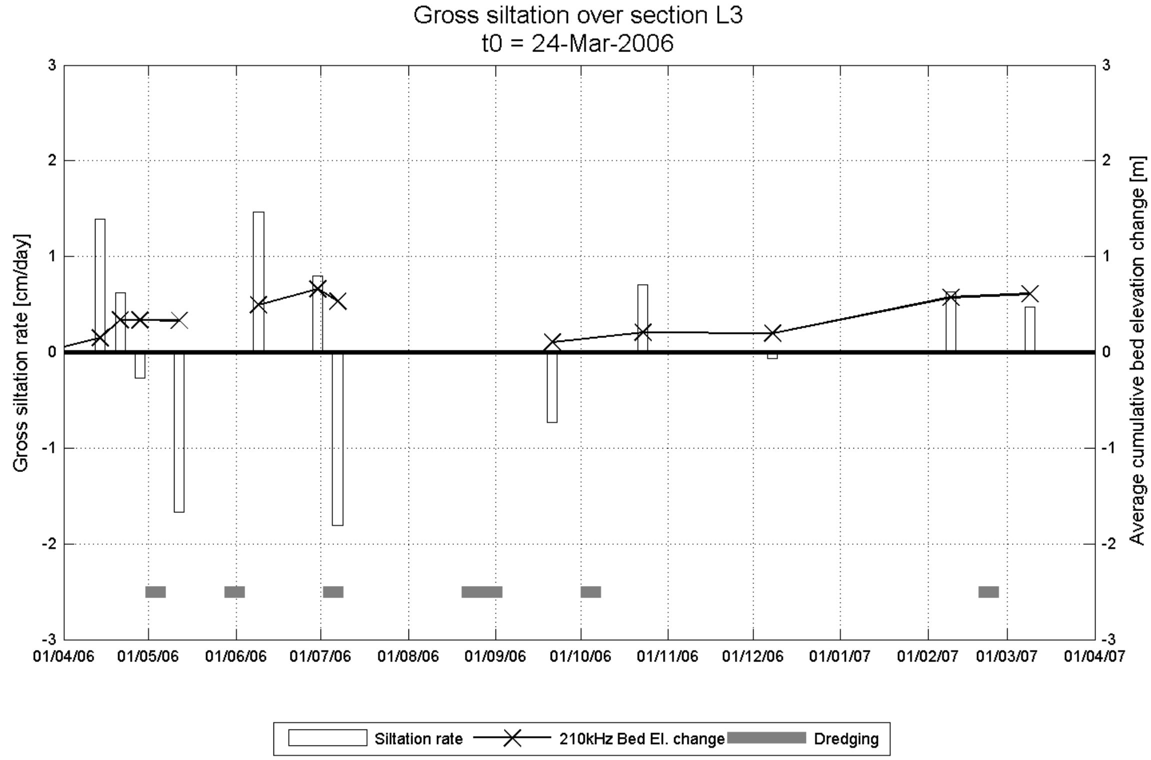
Data Processed by:

In association with :

I/RA/11283/06.117/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 24-Mar-2006

Data Processed by: IMDC

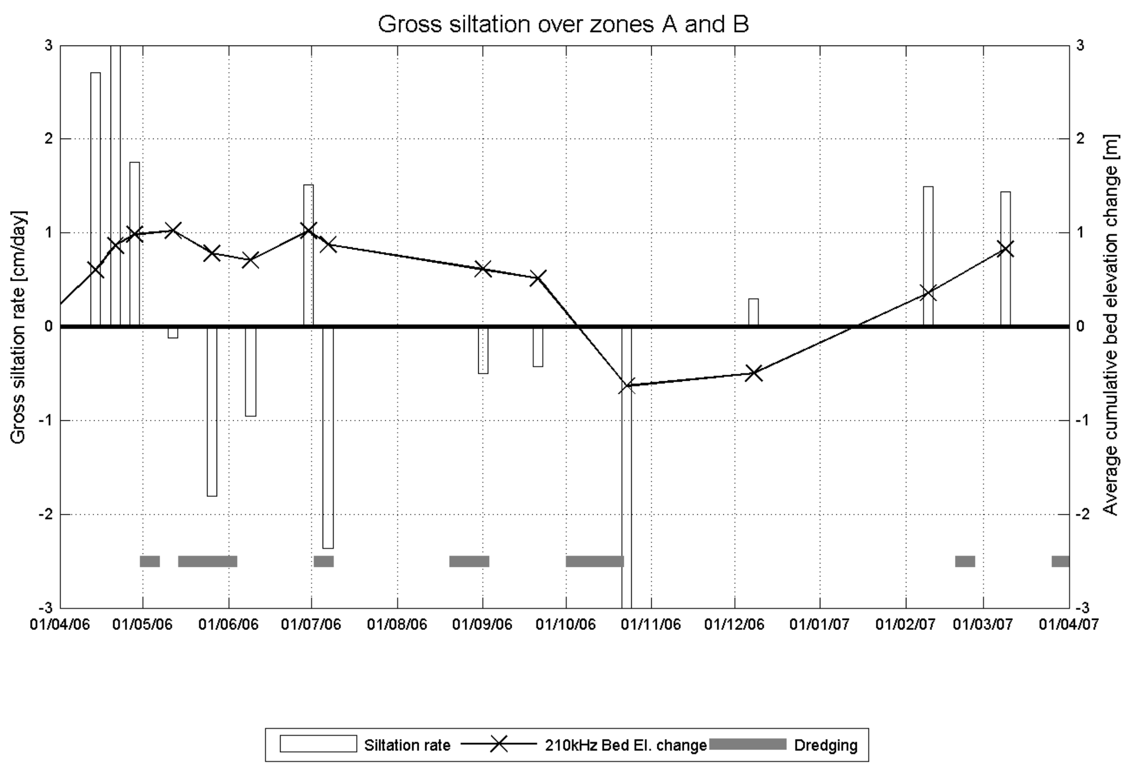
In association with :

I/RA/11283/06.117/MSA

C.4 Siltation rate complete Deurganckdok

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Gross siltation for zones 3A/3B/4A/4B/5A/5B
Reference level: depth sounding 24-Mar-2006

Data Processed by: IMDC
In association with :

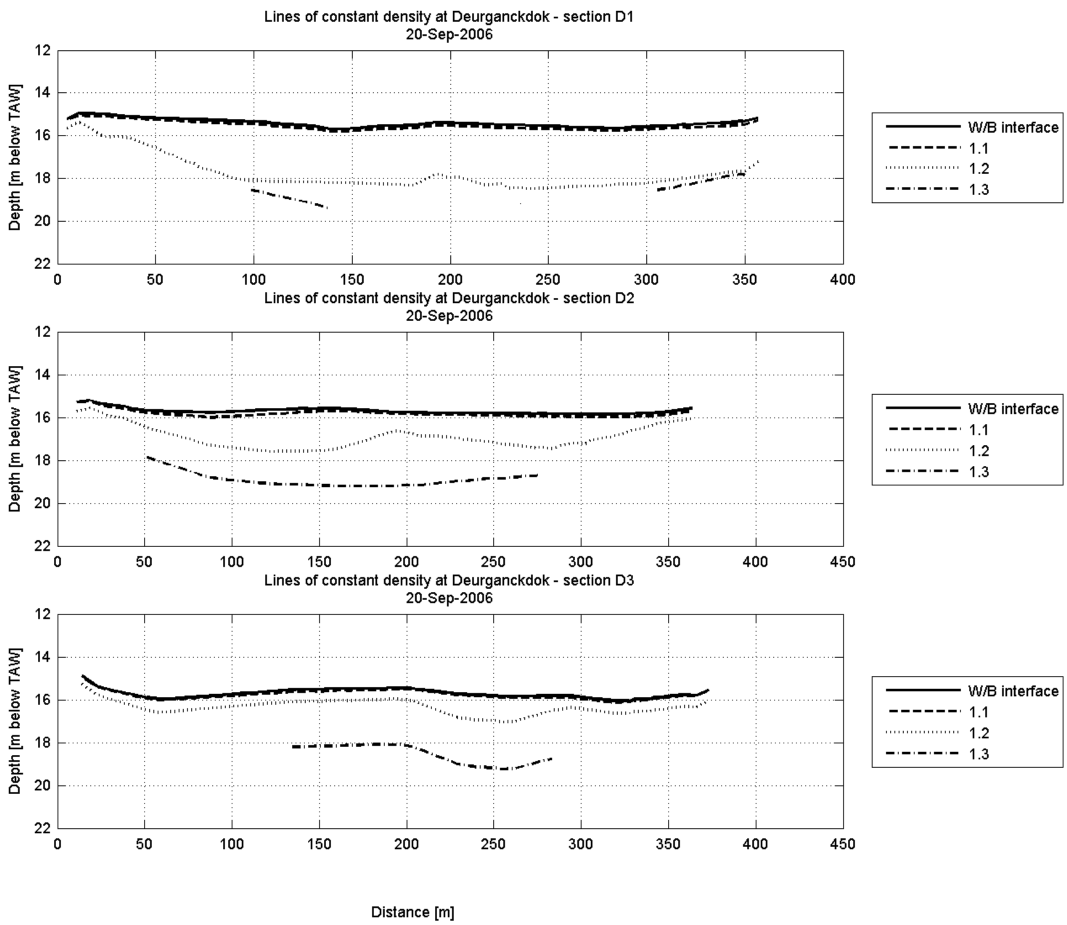
I/RA/11283/06.117/MSA

APPENDIX D.

DEPTH OF WATER-BED INTERFACE AND EQUAL DENSITY LAYERS

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	NaviTracker
	Location: DGD



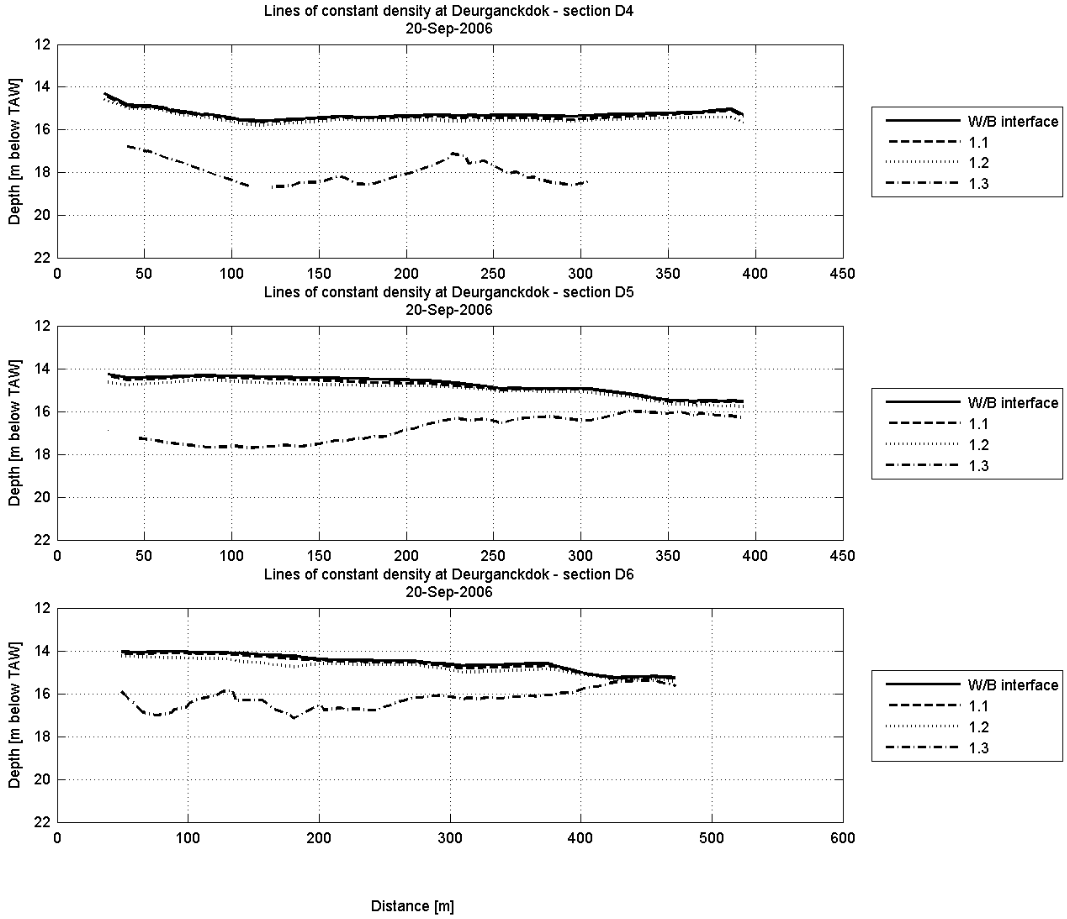
Data Processed by:

In association with :

I/RA/11283/06.114/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	NaviTracker
	Location: DGD



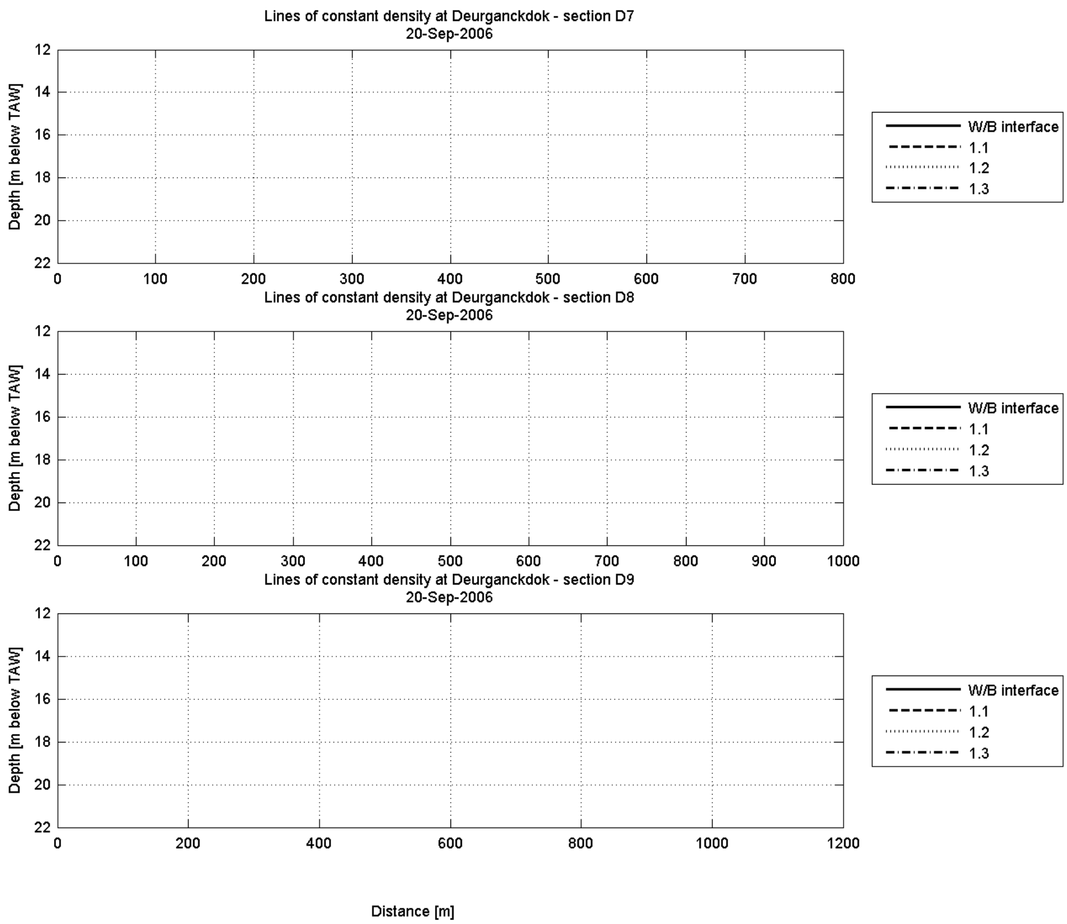
Data Processed by:

In association with :

I/RA/11283/06.114/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	NaviTracker
	Location: DGD



Data Processed by:

In association with :

I/RA/11283/06.114/MSA

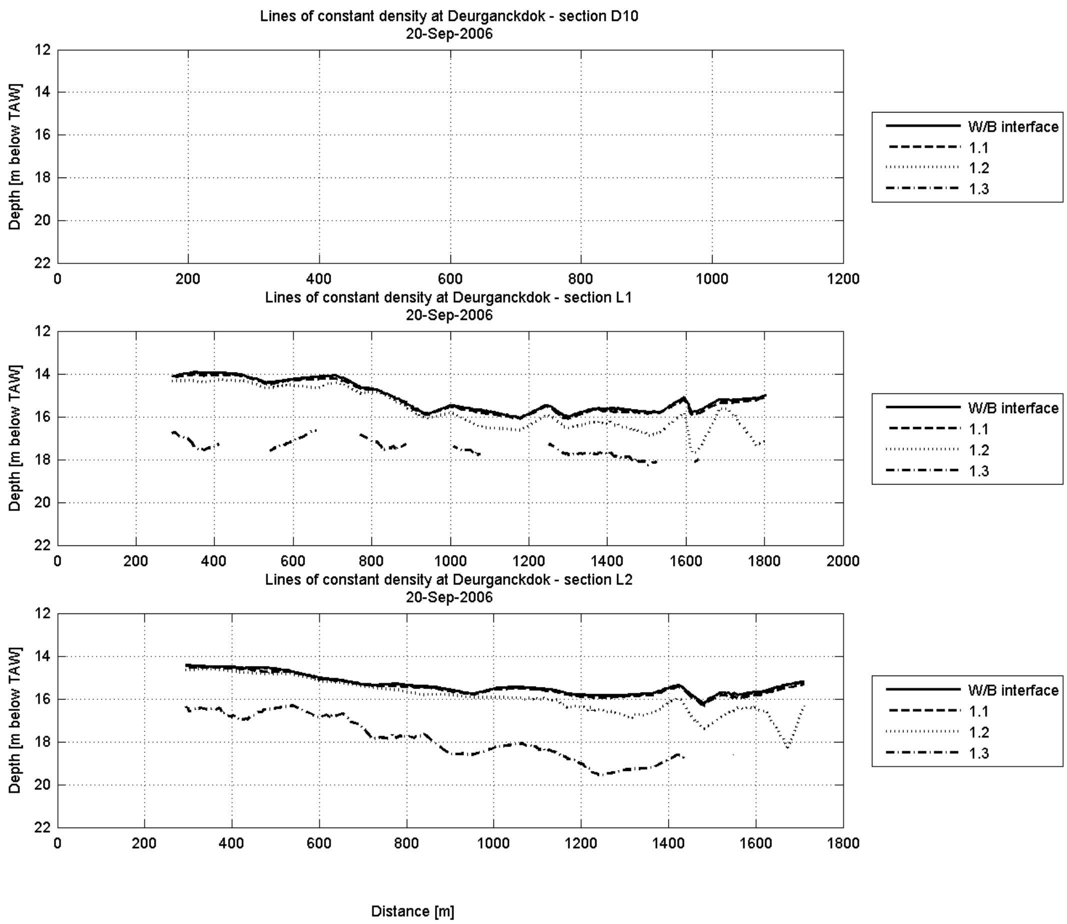
Long-term monitoring siltation Deurganckdok

Cross sections planes constant density

NaviTracker

Location:

DGD



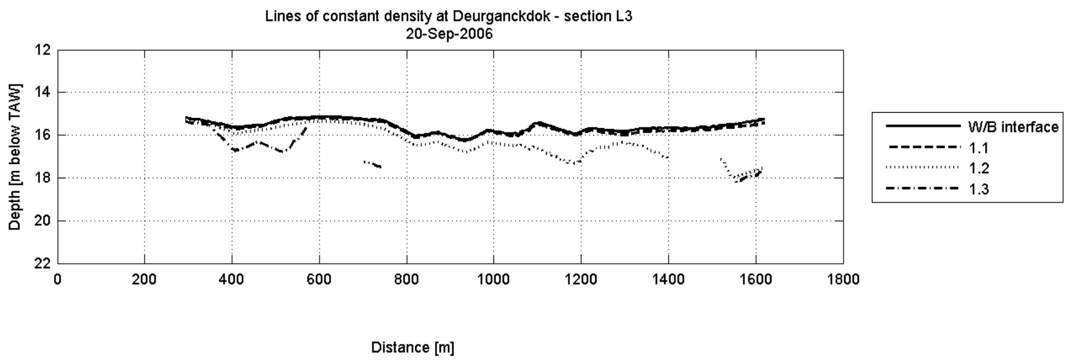
Data Processed by:

In association with :

I/RA/11283/06.114/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	NaviTracker
	Location: DGD



Data Processed by:

In association with :

I/RA/11283/06.114/MSA

APPENDIX E.

TOTAL DREDGED MASS

E.1 Tabular results

Total dredged mass in covered area per week (TDS)												
	30-apr-06	14-mei-06	21-mei-06	28-mei-06	3-Jul-06	21-aug-06	28-aug-06	02-Oct-06	9-Oct-06	16-Oct-06	19-feb-07	26-Mar-07
ZONE	7-mei-06	21-mei-06	28-mei-06	4-jun-06	9-jul-06	27-aug-06	3-sep-06	08-Oct-06	15-Oct-06	22-Oct-06	26-feb-07	2-apr-07
1	1114	0	0	0	43	0	0	0	4	0	0	2
2	4873	427	900	1409	4193	0	0	1858	218	0	1305	104
3a	8830	12823	15441	19072	9874	79	429	37638	67187	2598	69815	5495
3b	5350	14076	13763	18482	11337	5488	8634	18885	30686	69	5574	10211
3c	3405	5961	861	5354	54	4782	7608	2710	4199	0	0	7826
4Na	4360	59	98	90	13957	93	174	16761	10575	412	17744	1592
4Nb	3194	93	40	653	8796	3879	6927	9045	2147	20	11096	2613
4Nc	581	0	0	50	4	3210	1980	1847	132	0	0	1299
4Za	4781	4	0	407	11628	24	104	6498	178	6	5957	0
4Zb	6960	0	0	0	6722	4980	3167	5239	217	0	5442	0
4Zc	1817	0	0	0	0	1650	168	1088	0	0	0	0
5Na	400	0	0	0	2478	0	0	3565	3945	80	296	0
5Nb	282	0	0	0	1128	224	0	2475	89	0	141	0
5Nc	165	0	0	0	0	169	0	764	0	0	0	0
5Za	564	0	0	0	550	0	0	435	0	0	0	0
5Zb	1035	0	0	0	721	25	0	504	0	0	0	0
5Zc	249	0	0	0	0	41	0	414	0	0	0	0
Total	47960	33444	31103	45517	71485	24643	29192	109726	119576	3183	117370	29142

APPENDIX F.

HCBS2 REPORTS WINTER CAMPAIGN

Report	Description
Ambient Conditions Lower Sea Scheldt	
5.3	Overview of ambient conditions in the river Scheldt – January-June 2006 (I/RA/11291/06.088/MSA)
5.4	Overview of ambient conditions in the river Scheldt – July-December 2006 (I/RA/11291/06.089/MSA)
5.6	Analysis of ambient conditions 21/09/05 - 31/3/2007 (I/RA/11291/06.091/MSA)
Calibration	
6.1	Winter Calibration (I/RA/11291/06.092/MSA)
6.2	Summer Calibration and Final Report (I/RA/11291/06.093/MSA)
Through tide Measurements Winter 2006	
7.1	21/3 Scheldewacht – Deurganckdok – Salinity Distribution (I/RA/11291/06.094/MSA)
7.2	22/3 Parel 2 – Deurganckdok (I/RA/11291/06.095/MSA)
7.3	22/3 Laure Marie – Liefkenshoek (I/RA/11291/06.096/MSA)
7.4	23/3 Parel 2 – Schelle (I/RA/11291/06.097/MSA)
7.5	23/3 Laure Marie – Deurganckdok (I/RA/11291/06.098/MSA)
7.6	23/3 Veremans Waarde (I/RA/11291/06.099/MSA)
HCBS Near bed continuous monitoring (Frames)	
8.1	Near bed continuous monitoring winter 2006 (I/RA/11291/06.100/MSA)
INSSEV	
9	Settling Velocity - INSSEV summer 2006 (I/RA/11291/06.102/MSA)
Cohesive Sediment	
10	Cohesive sediment properties summer 2006 (I/RA/11291/06.103/MSA)
Through tide Measurements Summer	
11.1	Through tide measurement Sediview & Siltrofiler 27/9 Stream - Liefkenshoek (I/RA/11291/06.104/MSA)
11.2	Through tide measurement Sediview 27/9 Veremans - Raai K (I/RA/11291/06.105/MSA)
11.3	Through tide measurement Sediview & Siltprofiler 28/9 Stream - Raai K (I/RA/11291/06.106/MSA)
11.4	Through tide measurement Sediview 28/9 Veremans - Waarde(I/RA/11291/06.107/MSA)
11.5	Through tide measurement Sediview 28/9 Parel 2 - Schelle (I/RA/11291/06.108/MSA)
11.6	Through tide measurement Salinity Distribution 26/9 Scheldewacht – Deurganckdok(I/RA/11291/06.161/MSA)
Analysis	
12	Report concerning the presence of HCBS layers in the Scheldt river (I/RA/11291/06.109/MSA)